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FARM BUILDINGS

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FARM BUILDINGS

BY

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FARM BUILDINGS

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PREFACE

This book is a development of class and lecture notes used by the author in his classes at the University of Missouri. The subject matter is arranged to give a logical, progressive approach, introducing prerequisite information as it is needed in planning the various buildings in the farming industry. The division into chapters is made from the standpoint of a unit for study rather than for the subject matter contained. The questions and problems form the basis for student reports and discussions, and when a laboratory period is substituted for classroom work they aid the student in becoming familiar with the subject so that he can conduct the actual work with materials in the laboratory. The questions and problems offer opportunity for the instructor to create interest in the assignment for future work.

Class discussion followed by a short lecture period gives the student a chance to express what he has learned and enables the instructor to make application of the material to practical problems and to bring in outside information of interest.

A definite attempt has been made to avoid the handbook type of text in which the thinking has been done and the work of the student becomes merely a memorization of the conclusions of others. Emphasis has been placed on the assembling of facts and on guiding the thinking of the student so that he may arrive at his own conclusions.

The present-day consolidation of farms requires refitting of the buildings to the new arrangement. Because of the increased use of labor-saving machinery, field work is accomplished with fewer men and thus there is less manpower available for chore work around buildings. Efficient buildings, yards, gates, and arrangement of buildings are more essential than ever before. Additional information on these problems has been given in this second edition.

The book will be valuable to farm managers, appraisers, county agents, vocational teachers, and farm operators, who are continually confronted with problems relating to structures.

The problem may be one of fitting buildings to a farm, of determining the value of existing buildings, of planning new buildings, of replanning and repairing old buildings, of modernizing the home, or of arranging a building group. Whatever the problem, some suggestions will be found that will be of help in its solution.

Much of the material in the text is not original with the author but has been compiled from numerous sources and from discussion and correspondence with men in structures work in various colleges. No attempt will be made to give credit except in the courtesy notes found throughout the text. However, the author wishes to acknowledge the valuable help rendered by R. P. Beasley, instructor in agricultural engineering, University of Missouri, in checking and criticizing the contents.

JOHN C. WOOLEY.

COLUMBIA, MISSOURI,
May, 1946.

CONTENTS

PREFACE . . . . . PAGE V

Part I. General

CHAPTER

I. THE DEVELOPMENT OF BUILDINGS IN AMERICA. 1
II. FITTING BUILDINGS TO THE FARM 11
III. ESTIMATING THE COST OF NEW BUILDINGS. . . 18
IV. APPRAISAL OF EXISTING BUILDINGS. 25
V. THE OPTIMUM INVESTMENT IN BUILDINGS . . . 29
VI. FIELD AND FARMSTEAD PLANNING 36
VII. FENCES AND GATES. 52

Part II. Livestock and Poultry Buildings

VIII. PLANNING BUILDINGS FOR THE DAIRY ENTERPRISE. 62
IX. TYPES OF DAIRY BARNS. 74
X. BUILDINGS FOR THE POULTRY ENTERPRISE. . . 87
XI. BUILDINGS FOR THE HOG ENTERPRISE. 97
XII. BEEF CATTLE AND SHEEP 107
XIII. WORK-STOCK AND GENERAL-PURPOSE BARNS . 116

Part III. Air-conditioning Farm Buildings

XIV. HEAT: ITS MEASUREMENT AND TRANSMISSION . 123
XV. THE ENVIRONMENT FOR COMFORT. 130
XVI. HEAT AND MOISTURE RELATIONSHIPS. 139
XVII. VENTILATION. 146
XVIII. HEATING 154

Part IV. Building Materials

XIX. WOOD. 161
XX. WOOD FASTENERS 167
XXI. CONCRETE. 173

CHAPTER PAGE

XXII. CONSTRUCTION IN CONCRETE 180
XXIII. COBBLESTONE, CONCRETE, AND CLAY PRODUCTS 186
XXIV. SIDING, ROOFING, AND INSULATION 198

Part V. Structural Design

XXV. CARE, REPAIR, AND REMODELING 206
XXVI. BARN FRAMES 215
XXVII. DESIGN OF BEAMS 225
XXVIII. DESIGN OF COLUMNS AND FLOORS 234
XXIX. GABLE ROOF FRAMING 238
XXX. GAMBREL AND GOTHIC RAFTERS 245
XXXI. THE HIP ROOF 252

Part VI. Buildings for Storage

XXXII. FARM-MACHINERY STORAGE BUILDINGS 257
XXXIII. HAY- AND GRAIN-STORAGE BUILDINGS 265
XXXIV. THE SILO 275
XXXV. APPLE AND POTATO STORAGE 286

Part VII. The Farm Home

XXXVI. PLANNING THE FARM HOME 292
XXXVII. DESIGN AND CONSTRUCTION OF THE FARM HOME 307
XXXVIII. WATER SUPPLY AND SEWAGE DISPOSAL FOR THE FARM HOME 319

Part VIII. Drafting

XXXIX. DRAFTING AND INTERPRETATION OF PLANS . . . 326

APPENDIX—Suggested Laboratory Exercises I to XVI . . . 337

LIST OF VISUAL AIDS 345

INDEX 349

FARM BUILDINGS

PART I

General

CHAPTER I

THE DEVELOPMENT OF FARM BUILDINGS IN AMERICA

To get the most out of each assignment, it is desirable for the reader to review his own experiences as well as the principles learned in related courses bearing on the subject to be studied. The reader may have seen some of the famous homes of the pioneer period that are being preserved for the purpose of giving present and future generations a knowledge of the types of structures, the equipment, and the general mode of living prevailing at different times in our history. The Lincoln home, Mount Vernon, The Hermitage, Monticello, the colonial homes at Natchez, Miss., and scores of others tell a story that could not otherwise be so well understood or appreciated. The reader may have seen some of the old barns with their threshing floors, timber frames, and rows of stalls that indicate the size of the enterprise housed. Descriptions of farm homes and farm living are available in many books on the different periods. Moving pictures depicting pioneer times help visualize life during the development of our country.

PERIODS IN BUILDING DEVELOPMENT

1. The Pioneer Period.—The settlement of any new country is begun by the hardy pioneers who leave friends, relatives, and even civilization to undertake a self-sufficing existence far from the contacts of the settled community. During the settlement of our own country the pioneers wove their own clothing, dried meats and fruits to meet, as best they could, their needs in the

various seasons. They fashioned their own machinery, built their own homes, and protected them from wild animals and Indians with little organized help from the outside. Money was scarce, but little was needed, for there were no buyers; and even if salable commodities in excess of individual family needs had existed, it would have been impossible to reach a market over the poor timber trails that served as roads.

Schmidt and Ross, in their "Readings in the Economic History of American Agriculture," have this to say about this self-sufficiency period:

> From an economic point of view American society in 1815 can best be described as made up, for the most part, of small rural communities scattered over an immense area, having little commercial intercourse with each other or with the outside world. The only part of the country where this was not the case was a narrow strip of territory along the seaboard. The communities near tide water and on or near navigable streams in this strip, could and did carry on small commerce with each other, and a large commerce with foreign countries. But everywhere else the people lived in isolated, self-sufficing communities which produced practically everything which they consumed. Everyone tilled the soil, and every farmer was a 'Jack of all trades'. It may be noted that this feature of American society was much more prominent in 1815 than it had been before the revolution. Then the settled area where these conditions prevailed could not have included more than about a third or possibly a half of the population. The rush of the people into the West which followed the revolution carried the settlements to the Mississippi and beyond by 1830 and spread the population over a large part of the intervening territory. The back country, as it was called, where these conditions were most prominent, was expanded until it made up a large part of the country. Probably two-thirds of the population now lived under conditions of commercial isolation. It did not, as is commonly assumed, bring any economic advantage to the people as a whole; that is, it did not increase their ability to produce wealth, but rather had the opposite effect. It greatly increased what has always been the chief obstacle to the production of wealth in American society, namely, lack of division of labor. In spite of the great energy and efficiency of the individual laborers, American industry in general was not highly-productive in colonial times. There was always plenty of rude comfort, but not much wealth. It was easy to produce the bare necessities but difficult to produce anything more.

Building Requirements.—The function of buildings in this self-sufficing period was limited to the protection of the farm

family and their food supply from wild animals, Indians, and the weather. The dwelling, although not large, was the principal building on the farmstead. In the timbered country the log house was the universal type. Logs were hewed on two sides and fitted together as closely as possible. The cracks were chinked with mud or lime mortar. The logs were notched and fitted together at the corners of the structure. Foundations were of stone or of wood blocks or possibly of logs laid in a trench at the beginning of the structure. Pole rafters and split shingles made the roof. The doors, made from hewed lumber, were fastened together with wood pins and hung on wood hinges. Heat was furnished by a single fireplace in the one-room cabins and by one fireplace in each end of the two-room cabins. Those fireplaces, made of rocks or of logs and clay, were built large so that logs of considerable size could be rolled onto the fire.

The pioneer home of the prairie was the sod house. This was the logical type of building for several reasons. Building material for construction of any other type must be brought long distances, and therefore the log cabin of the forest region was out of the question. Fuel was scarce, and the sod house was easily heated. Winter blizzards swept across the plains, and the sod houses, built partly into a hillside or ledge, gave the desired protection. Prairie fires were common, and the sod house was built to resist fire. Bess Streeter Aldrich in her book "A Lantern in Her Hand" gives this description of a sod house built on the Nebraska prairie:

> Will started a sod house. He cut strips of sod three feet long and laid them up as a mason would lay so many huge bricks, leaving places for the windows. The inside dimensions of the house were thirty by eighteen so that when the partition was run through, the general living room was eighteen by twenty, and the bedroom eighteen by ten. The house was covered with sod for a roof. The rough edges of the black sod of the house were treated to a thick coat of mud plaster and a board floor was laid. The low partition and the crude board door Abbie papered with hoop-skirted feminine paragons of style out of Godey's Lady's Book, from which vantage point they looked down upon the humble interior with supercilious pride. This, then, was the house into which Abbie moved from the prairie schooner.

2. A Century of Expanding Markets.—During the hundred years from 1815 to 1915 there was a steady growth and develop-

ment in agriculture, more or less correctly characterized as a period of expanding markets. During most of this period the thoughts of agriculturists were given to problems of production. Except for a few short periods during the century, the market absorbed all that could be produced. Most of this market came through the development of internal trade resulting from a division of occupation among the population. Instead of each man's attempting to supply all his own needs from his own labor, the farmers were selling wool and buying clothing, selling hides and buying shoes and harness, and selling wheat and buying flour. Schmidt and Ross have this to say about the development of internal trade:

> One of the striking features of the economic development of this country during the first half of the nineteenth century was the rise of internal trade. While such trade had existed to some extent even in colonial times, its amount was too small to be of much importance down to as late a date as 1815. The New Englanders carried a little fish and a few manufactured products like shoes, tinware, and wooden clocks to the middle states and the South, and brought back a little grain, and in later years, a little cotton. The merchants of the seaboard cities sent a few articles of necessity and luxury to the 'back country' and the Ohio Valley. A few herds of cattle were driven eastward from these regions to the seaboard, and a little produce was sent down the Ohio and Mississippi to New Orleans. But the value of all this trade prior to 1814 was insignificant. During the forty-five years from 1815 to 1860, these small rivulets of internal trade swelled into a great volume which, at the latter date, equaled in value, if it did not exceed, the foreign commerce of the country. It is extremely difficult to find out the facts concerning the growth of this internal trade. It can only be measured by the tonnage of steam boats, the growth of cities, and towns, and the development of railroads and highways.

Division of Labor.—During this century of expanding markets a practice of division of labor developed in America. Adam Smith, a famous English economist, rightly regarded this practice as the most important factor affecting the ability of a community to produce wealth. As division of labor grew it became possible for the first time for an individual to devote himself to the production of one or a few articles best suited to his productive ability and to depend on other members of his community, or even upon foreign markets, for commodities he could produce only at a disadvantage. The markets for various commodities

that now arose opened the way, also, for organization of labor in various industries in which such organization had been unknown before. This organization began to show itself in the ironworks of Pittsburgh, in the slaughterhouses and machine shops of Cincinnati, the hemp mills of Kentucky, and the iron mills of Michigan, as well as in other industrial centers. The economic advantages that had been enjoyed before only by the people of the seaboard were now extended to the whole country. There was nothing spectacular in these changes. They came about gradually and quietly; but in the course of a generation they wrought what amounted to an industrial revolution over the greater part of the country. There had developed from the Jack-of-all-trades farmer of the pioneer period a farmer who devoted the major part of his time to the production of one or two products that, because of his ability or environment, he could produce at an advantage. There began a division of occupation in agriculture.

The Country Carpenter.—Another group of men, known as *country carpenters*, was developing at this same period. In those days the name *carpenter* was given a man upon completion of a long period of apprenticeship under the guidance of an experienced carpenter. His pay was small and his work strenuous.

Weeks of work by the carpenter and his apprentice were required before the men of the community were called together for a barn raising. The frames for the building were made from heavy timbers connected by mortice and tenon joints and fastened by wood draw pins. Some posts had mortices on all sides and at various heights to hold the braces and nailing girts in place. On the eventful day of the "barn raising" the carpenter in charge must have each post, brace, plate, and tie framed with the proper size of mortice and tenon and piled in the order that would be needed in assembling the structure.

Much honor was accorded the carpenter if each piece went into its place without trouble on the day of the "raising." Through his long apprenticeship the carpenter acquired training of mind that enabled him to see the barn and, in fact, each timber in it before he had begun the work of framing, and, along with this, he acquired the skill to shape each piece to the accuracy needed for mass assembly. The picturesque profession of the country carpenter was outmoded with the changes that came

with advanced methods, but many sturdy structures still remain as evidence of his ability.

The lumber for many of these structures was produced on the farms on which they were built. Trees were cut and logs hauled to the mill and sawed into pieces needed for the building. Thus the barn or house, as the case might be, represented a great amount of work but a limited amount of cash.

Building Requirements.—The building requirements were greater but probably no more exacting than those of the self-sufficing period. The ready sale for surplus products caused most farmers to practice in their farm building program the general slogan of the time, "bigger and better." Size was emphasized at the expense of service. Little thought was given to the influence of the structure on the quality of products marketed, on the health of animals housed, or on the efficient use of the farmer's time. Less attention was given to building cost, because the increase in farm values easily covered the cost of buildings, even though extensive building was done.

The livestock of this period, although not so productive as present breeds, was probably hardier and less susceptible to disease. Smaller herds and wider range may have lessened problems of sanitation. Farm products were not sold quite so extensively, and inspection was not so rigid as it is at present. Many times steers were carried along on maintenance rations until they were two or three years old and then fed out for the market. Dairy cows were of the dual-purpose type and did not need as careful housing as do the high-producing cows of today.

Farm Labor.—A very efficient class of farm labor could be hired during this period. The hired men were recognized as a definite class of individuals in rural life. They received a low wage, because they were serving an apprenticeship during the time of their employment. Four or five years was usually required in which to master the art of farming and to accumulate sufficient capital to make a beginning in the business of farming for themselves. Saving time in chores was not of much importance, because plenty of help was available. If two people were needed to transfer horses or cows from pasture to barn they were available. Many of these hired men worked about the farm during the winter months for their board, room, and laundry, since there was no other employment to be had.

3. The Modern Period.—The present period, or the period of world competition, is characterized by efficiency in every line of endeavor. Manufacturing through mass production means standardization of parts and specialization of labor, resulting in greater production per man than ever before. By use of automatic machinery, one factory worker often does the work formerly requiring 20 men. Transportation has been speeded up so that raw materials may reach the factory and finished products reach the consumer in a minimum of time and with a very greatly reduced force of workers. Other occupations have developed and increased their efficiency in much the same manner, and therefore it becomes evident that agriculture must also advance with equal efficiency, because agriculture is in competition with other industries for men. Today no class of hired men is bound to the soil. They have the means of knowing what men of equal ability are getting per hour in other kinds of work, and they have facilities to travel to points where such jobs are to be had. The laborer must be given power and equipment so that he can be equally productive in agriculture as in industry if the farmer is to bid for his services. Manufacturers use their laborers, not to furnish power, but to guide or supervise the machine that is driven by a force possibly thousands of times as powerful as the operator himself. The modern farmer must equip his farm with buildings that will house his livestock so as to prevent the inroads of disease; to enable him to produce a salable product; to provide comfort in order to secure economical gains; and to enable him to care for a large enough herd to make a business of sufficient size to be profitable. This may or may not mean a larger investment, but it will mean a more careful analysis of the farmer's needs and of the types of structures available to meet them.

Building Requirements.—The modern farmer depends for his cash income upon the things he can produce to sell. The amount of his profit depends upon the quantity he has to sell, the price he sells it for, and the amount it cost him to produce it.

$$Q \times (S - C) = P$$

where Q = quantity.
S = selling price.
C = cost of production.
P = profits.

If he can increase S or decrease C, he will increase his profits. If he increases the quantity of products he may increase either his profits or his losses, depending upon the relationship of sales price and cost of production. One way of increasing the selling price is to improve the quality. In the case of dairy products, especially milk, he must have a high-quality product in order to sell it at all. Consumers are demanding quality and in order to make sure they get it are specifying conditions under which the product is produced and handled. These rules are set forth in the particular milk ordinance that applies to the farmer's community. These ordinances are usually concerned with provision of healthful surroundings for the cow and sanitary environment for milking and handling milk. Practices such as removal of manure, handling of hay, sterilization of utensils, care of the milk, and even clothing of the worker come in for regulation. In some sections farms are rated A, B, or C according to the extent to which they meet the requirements for production of quality milk. Dairies in some sections pay about \$4, \$3, and \$2 per hundred pounds for milk from class A, B, and C farms. This is sufficient inducement to encourage farmers to improve their facilities and procedures.

High-quality poultry products are being recognized in many markets. Some states have improved breeds, procedures, and equipment to secure and maintain a high-quality product. They have established a reputation for dependability and enjoy a differential in price. The formula for profits applies again to this enterprise, and a part of the improvement in quality and of the profit derived may be credited to buildings.

Considerable attention is being given to improvement in quality of hay and grain, not so much that it might bring a higher price on the market but that the feeding value may be improved. Barn curing of hay and the drying of corn and other grain is being carried out to secure improvement in feeding value.

Thousands of dollars are being spent by farmers for commercial feeds. These feeds are made up for the most part from products of the farm. By curing hay and grasses cut at the proper time to secure their full value and by doing some processing on the farm, much of the expense of advertising, packaging, and transportation from and back to the farm could be eliminated.

The procedure today calls for the elimination of low-producing individuals in herds and flocks. High-producing individuals are then provided with the environment that will give them every chance to produce efficiently. A study of the development and improvement of various domestic animals gives some clue to the environment under which they will give best results. This information has been given consideration in design of modern structures. Scientific studies are being conducted to determine the reaction of different animals to varying environment and should enable great improvements to be made in housing in the future.

Manufacturers spend much time and energy in determining the best arrangement and design of equipment for carrying out various operations in their plants. The frequency of recurrence of an operation, the amount of energy expended in doing the work, and the amount of drudgery connected with it govern the amount of attention that can be justifiably devoted to making improvements. The matter of safety is coming in for increased consideration also. The elimination of difficult and undesirable tasks about the farm has an influence on the problem of hiring help and of keeping young people on the farm. The use factor is almost as important in an investment in a building as it is in a machine for the factory. Many factory machines can be used day and night and can thus liquidate a rather large investment. Buildings of necessity have a much lower use factor, but, by planning buildings for multiple uses and by providing enterprises with different seasonal demands, a higher use factor can often be secured. The central farrowing house is often used as a protected feeding place for stock hogs in summer. The brooder house may be used for broiler production between seasons. Machinery and cattle may be shifted between barns at the farmstead and open shelters in the pasture at different seasons.

All of this adds up to a decrease in cost of production. Buildings on the modern farm must increase rather than decrease the returns from the farming operation. They must make the farming business more desirable if their cost is to be justified.

Questions and Problems

1. Compare farming in the three periods as to self-sufficiency in (*a*) mechanical equipment, (*b*) clothing, (*c*) shoes, and (*d*) food.

2. What effect did the extension of railroad lines into a community have on the objective of the farmer? On the kind of buildings he needed?

3. "Problems of sanitation are becoming increasingly difficult in modern farming as compared to pioneer times." Why?

4. "The farm in this modern period is a better place to live than it was in either of the other periods." Justify this statement.

CHAPTER II

FITTING BUILDINGS TO THE FARM

The ideal situation in regard to the size and capacity of service buildings is to have them equal to the productive capacity of the farm. The farmer who balances the livestock and poultry projects with the ability of the farm to produce pasture, hay, and grain, and then provides buildings of proper size to house this livestock and feed, is not subjected to extra expense from overbuilding. If he does not provide enough buildings, then animals are overcrowded or inadequately housed. An experienced poultryman made the statement that a certain-size house would produce a certain number of eggs per year. He said, "You can put more hens in the house, but you won't get any more eggs." If hens are overcrowded they are much more susceptible to disease and as a result the losses in numbers may be even greater than the loss in production. Perhaps other enterprises may be influenced less by overcrowding, but in most cases the results will be much the same. On the other hand if the farmer reduces the size of enterprises to fit buildings which are inadequate, then he will not be using the full productivity of the farm to the best advantage.

Farm buildings, long considered as real estate improvements, are now being considered as a part of the equipment necessary for the successful operation of any enterprise.

SELECTING THE ENTERPRISES FOR THE FARM

4. In selecting enterprises there are three important factors to be considered. First in importance is *correct use of the land.* If the projects selected do not include plans for maintaining or perhaps building up the productivity of the soil, then, no matter how ideal the other parts of the plan, the project is certain to fail in the end.

For example, a rolling farm has been badly farmed out with row crop production. It is evident that it should be planted to small grain, meadow, and pasture, and in addition a water-

management plan including terraces is needed. Dairy farming is probably the best selection to secure this correct land use. If the owner continues to farm with corn and soybeans as major crops he will certainly be doomed to failure in the end no matter how good his buildings or his methods of cultivation.

5. The second factor to be considered in selecting enterprises is the *availability of markets.* If a farmer is to do more than provide a living for his family he must have something to sell which the market demands. In some localities there is a constant demand for whole milk. This would warrant consideration of the dairy enterprise. A good price and a steady demand for fresh eggs makes the poultry enterprise attractive. A good market for sweet cream makes a combined dairy and hog or a dairy and poultry enterprise desirable. A farm located at some distance from market or on a dirt road, making daily delivery difficult and uncertain, might require selection of beef cattle or beef cattle and hogs as the principal enterprises, because they can be marketed as desired. If high-quality hay is in demand some farmers may be justified in producing it as a major enterprise. There is a fluctuation in the demand for farm products from time to time, making one enterprise more profitable than another for a time. It probably will not pay a farmer to drop one enterprise and set up another with each change in demand; however, he can emphasize one over another from time to time and take advantage of market changes. He will maintain his foundation stock in the enterprises that are being curtailed so that he will not be penalized when this particular project again demands preference. Such a plan of changing the emphasis on different enterprises may call for one building which can be adapted cheaply and quickly to the hog, sheep, poultry, or dairy project.

Marketing is such an important factor in success that it deserves careful consideration in the selection of enterprises.

6. The third factor to be considered is the *preference and ability of the operator.* Some men enjoy working with dairy cows; others find their liking in beef-cattle production, in swine production, or in poultry. Still others enjoy using machinery and prefer crop-production enterprises. It is a very fine situation when the farmer secures a farm where his preference in enterprises fits into the land use and marketing situation existing.

Such a farmer will enjoy his work and in a high percentage of cases will be successful.

The late Chancellor Lindley of Kansas expressed this truth as follows: "Do the thing that you like to do and then get paid for it."

DETERMINING THE SIZE OF THE ENTERPRISES SELECTED

7. In order to determine size of the business the *productive capacity of the land* must be known. The productive capacity

TABLE 1.—SOIL-PRODUCTIVITY CLASSIFICATION*

Class	Description	Principal upland series
1	Productive land, all suitable for cultivation. Average corn yields 40 bu. or more per acre	Marshall, Grundy, Summit
2	Above medium productivity, all suitable for cultivation. Average corn yields 30–40 bu. per acre	Edina and Carrington, better grades of Knox, Shelby and Pettis
3	Medium productivity, practically all tillable. Average corn yields 20–30 bu. per acre	Crawford, Decatur, Eldon, Hagerstown, Leslie, Memphis, Oswego, Putnam
4	Below medium productivity. May or may not be tillable, but suitable for pasture. Average corn yields below 20 bu. per acre	Bates, Baxter, Cherokee, Lindley, Tilsit, Union, Gerald
5	Mainly forest or rough pasture, because of low fertility, rough surface, erosion stone content, or wet condition	Ashe, Boone, Clarkville, Hanceville, Marion, Lebanon

* Replanning Missouri Farms, *Mo. Ext. Circ.* 375.

of different soil types in Missouri can be found from Table 1. For farms in other states a similar table will be needed.

Knowing the type of soil on his farm, an operator will be able to select the productivity classification from Table 1 and use it to find from Table 2 the acres of pasture and crop land required to support one animal.

Before starting on the problem of budgeting the land, however, it is necessary to know the number of acres in permanent and in rotation pasture. If the plan of pasturing small grain in

the spring and again in the fall, together with lespedeza thru the dormant period for blue grass, then the carrying capacity of the permanent pasture may be increased 50 per cent. It is usually advisable to use the pasture completely because it is difficult to sell it off the farm in any other way.

TABLE 2.—ACRES OF PASTURE AND CROPS ON DIFFERENT CLASSES OF LAND REQUIRED TO SUPPORT ONE ANIMAL*

Kind of animals	Class 1		Class 2		Class 3		Class 4		Class 5	
	Pasture	Cultivated	Pasture	Cultivated	Pasture	Cultivated	Pasture	Cultivated	Pasture	Cultivated
Dairy cows, full ration	1.5	2.25	1.75	3.25	2.25	4.50	3.00	6.00	4.00	
Family cows	1.89	1.91	2.20	2.76	2.84	3.83	3.80	5.20	5.10	
Dairy heifers, second year	1.32	1.53	1.52	2.20	1.95	3.06	2.62	4.07	3.46	
Dairy heifers, first year	0.60	0.95	0.70	1.36	0.90	1.89	1.20	2.50	1.60	
Beef cow and fed calf sold in fall	1.90	1.91	2.22	2.76	2.88	3.81	3.81	5.1	5.1	
Beef yearling, full fed, dry lot, no silage, 140 days	....	1.04	....	1.50	....	2.06	....	2.76		
Ewe with lamb, sold early	0.32	0.20	0.37	0.28	0.47	0.41	0.63	0.54	0.84	
Lambs, Western fed, dry lot	....	0.37	....	0.53	....	0.74	....	1.00		
Sow, including 13 pigs, sold at 200 lb.	....	5.40	....	7.80	....	10.8	....	14.4		
Hen	....	0.026	....	0.038	....	0.053	....	0.071		
Work horse	0.86	2.05	1.00	2.95	1.28	4.10	1.71	5.50	2.27	
Colt, first year	1.20	1.64	1.40	2.35	1.80	3.28	2.40	4.36	3.20	
Colt, second year	1.50	2.10	1.75	3.00	2.25	4.20	3.00	5.60	4.00	

* Replanning Missouri Farms, *Mo. Ext. Circ.* 375.

To begin with, it is necessary to budget a certain amount of pasture and crop land to the more or less fixed enterprises essential to the operation of the farm. Work stock, a poultry or hog enterprise kept to supply family needs, etc., are examples. The remainder of the land can then be allotted to the selected enterprises in the order of their importance to the business.

Example: The following is an example showing use of tables in determining the livestock-carrying capacity of a farm. Size 160 acres, soil of high productivity, 26 acres in permanent pasture, 4 acres in the farmstead, 6 acres in roadways and 124 acres in cultivation. This cultivated land is divided into four fields, one of which is in pasture following

meadow each year. There is a good market for whole milk and the dairy is to be the main enterprise. Twenty-five hens will be kept to supply the family needs. Four head of work stock is used on the farm. Six calves are kept each year to maintain the herd.

After taking out the acres of pasture and crop land needed for the work stock and the hens the remaining acres are available for the dairy enterprise. One dairy cow plus her complement of young stock requires 1.88 acres of pasture and 2.75 acres of crop land. By dividing the pasture available by 1.88 we find that it will carry 28 dairy cows with the six calves and six yearlings and 78 acres of crop land will be needed for them.

Recapitulating, this particular farm would be subdivided and utilized as follows:

Livestock	Pasture, acres	Crop land, acres
4 head work horses	4	8
25 hens	0	1
28 dairy cows	42	63
6 yearlings	8	9
6 calves	4	6
Surplus	0	5
	58	92

SELECTION OF BUILDINGS NEEDED

To house properly any animal enterprise a certain amount of pen or stall space, together with crib, bin, and mow space will be needed. From Table 3 the amount of space needed for these projects may be secured.

TABLE 3.—BUILDING-SPACE REQUIREMENTS FOR DIFFERENT ANIMALS

Kind of animal	Number of stalls	Pen space, square feet	Hay stored, tons	Corn, bushels	Small grain, bushels	Silage, tons
Dairy cow, full-grain ration	1	65	1.2	20	24	2.6
Dairy heifers	1	40	1.3	10	12	1.5
Beef cow	1	40–60	1.0	10	12	0.5
Beef yearling, full fed, dry lot no silage	..	28–42	0.36	33	38	
Ewe with lamb, sold early	..	15–20	0.15	1	2	
Lambs, Western, fed in dry lot	..	15	0.10	2	0.5	
Brood sow	..	50	.....	10	12	
Pig to 200 lb	..	20	.....	13	15	
Hen	..	3 or 4*	.....	0.50	0.37	
Work horse	1	.....	1.8	34	59	
Colt, first year	..	36	1.0	9	17	
Colt, second year	..	60	1.3	12	21	

*Three for small and four for large breeds.

In most cases the farmer will not have special designs made for his buildings but will select sizes of buildings to suit his needs from standard plans available or by adapting plans with which he is familiar.

For the livestock selected in the illustrative example the building-space needs would be as follows:

Kind of animals	Number of stalls or	Floor space needed, square feet	Hay space, tons	Corn, bushels	Small grain, bushels	Silage, tons
4 work horses	4	.....	7.2	34	59	
25 hens	..	75 or 100	....	12	9	
28 dairy cows	28	1,820	34.0	560	672	73
6 heifers	6	240	7.8	60	72	9
6 calves						

BUILDINGS SELECTED TO MEET THE ABOVE SPACE REQUIREMENTS

Animals	Building	Content cu. ft.
4 head of work stock	A combination horse barn and machinery-storage building, 28 by 60 ft.	24,400
25 hens	10 by 12 ft. brooder house converted into a laying house	960
28 dairy cows	34 by 114 ft. dairy barn	82,000
6 calves and 6 heifers	14 by 16 ft. milkhouse	2,250

Questions and Problems

5. Find the livestock-carrying capacity and building-space needs of the farm used in the illustrative problem when beef cows with calves fed out in one year is the main enterprise. A poultry flock of 300 hens makes up a minor enterprise. Tractor power is used for farming.

6. Find the building needs for a farm of 280 acres, with Putnam soil and 70 acres in permanent pasture and 12 acres in the farmstead and in waste land. The remainder is farmed with the following rotation: corn, soybeans, wheat plus lespedeza two years. The soys are sold as a cash crop and must be taken out of the crop acres for livestock. Lespedeza is pastured off the first year and wheat is pastured each spring and fall, adding 30 per cent to the carrying capacity of the permanent pasture. Four head of work stock supplement the tractor power on the farm. Sheep, beef cattle, hogs, and poultry make up the enterprises. Balance these enterprises to make best use of the crops on the farm and list the building requirements.

Reference

The Balancing of Farm Structures with Farm Capabilities, *Agr. Eng. J.*, Vol. 22, No. 9, p. 311, September, 1941.

CHAPTER III

ESTIMATING THE COST OF NEW BUILDINGS

Four different methods of estimating the cost of new buildings are being used and will be presented here.

8. Labor-plus-material-cost Method.—Contractors, in making bids on new construction, have found it necessary to compile accurate data on costs, and some very useful systems have been developed. These men have kept records of the man-hours required for doing certain jobs until they know rather definitely what the construction costs of these standard jobs on any building will be. Most new buildings consist of different combinations of the more or less standard jobs, and therefore the labor cost of erecting a new building can be predicted quite accurately. The following are given as average labor requirements to complete certain specified pieces of work.

In an eight-hour day one man can do any one of the following jobs: erect 500 ft. b.m. of studding, joists, rafters, or sheathing; erect 400 ft. b.m. of shiplap or drop siding; apply 350 ft. b.m. of weatherboard or matched flooring; 1,000 ft. b.m. of barn boards; lay 1,500 shingles; fit and hang 7 doors or check-rail windows; cover 80 sq. yd. of surface with paint; or place 15 sacks of cement. If a material list for a building is available the carpenter-hours can be determined, and if the prevailing wage scale for workmen is known, a very close approximation to actual construction cost can be secured. Cost of materials added to this gives the total cost.

9. Material-cost-plus-a-percentage-for-erection Method.—A less accurate method, consisting of material cost plus a certain percentage for erection, is used where time will not permit the use of the labor-plus-material-cost method. In this plan the material cost is secured and a percentage added for labor (20 per cent for rough buildings and 40 per cent or even more for farmhouses, 33 per cent usually being required for dairy and horse barns).

10. Unit Cost Method.—Unit costs of foundations, walls, floors, and other major items have been listed below to aid in forming a general idea of the cost of work. These costs are for ordinary construction, all materials being purchased at retail prices and all labor hired at rates common in farm communities. The range in costs is intended to cover variations in different parts of the country. Where native materials may be obtained at low prices or when much of the work is done by the owner or his family, costs may be much less than those shown.

TABLE 4.—UNIT COSTS OF BUILDING OR REMODELING

Item	Range of Cost
Excavating—usually done by owner	
Foundations, per linear foot of wall or sill:	
Masonry wall 3 ft. high, with sill	$1.25–$2.25
Masonry wall 5 ft. high, with sill	1.75– 3.25
Masonry wall 7 ft. high, with sill	2.25– 4.25
Masonry piers 2 ft. high, sills 6 by 8 in	0.35– 0.55
Masonry piers 4 ft. high, sills 6 by 8 in	0.45– 0.75
Interior floor support, post and girder; per linear foot of girder	0.25– 0.40
Cellar floor, 4-in. concrete, per square foot	0.12– 0.20
Drain for foundation: 4-in. tile, laid, per linear foot	0.10– 0.15
Waterproofing floor and wall, per square foot	0.10– 0.15
Exterior walls, per square foot of plain wall surface. For gable ends, add to cost of plain wall per square foot	0.10– 0.15
Vertical board and batten or horizontal siding with framing; outside painted, interior net finished	0.12– 0.18
Vertical board and batten or horizontal siding with framing; outside painted, interior sheathed and papered on cheese-cloth	0.20– 0.30
Siding, studs 16 in. on centers; outside painted, interior wainscot and wallboard	0.20– 0.30
Siding on sheathing, studs 16 in. on centers; outside painted, interior plastered and papered	0.30– 0.40
Brick 3 in. thick, brick veneer, or brick backed with 4-in. tile, inside plastered and decorated	0.40– 0.60
Cinder or concrete block, 8 in. thick finished both sides with cement paint	0.20– 0.30
Cinder or concrete block or hollow tile; outside stuccoed, inside plastered	0.30– 0.50
For furring and board insulation as plaster base for masonry walls add to above figures per square foot	0.08– 0.15
Ceilings, per square foot:	
Sheathed, papered on cheese cloth; joists 2 by 6 in., 2 ft. on centers	0.10– 0.15

TABLE 4.—UNIT COSTS OF BUILDING OR REMODELING.—(*Continued*)

Item	Range of Cost
Lath and plaster, papered; joists 2 by 6 in., 16 in. on centers	$0.12– 0.20
Lath and plaster, papered (under second-floor joists)	0.08– 0.15
Insulating board or wallboard, not painted; joists 2 by 6 in., 16 in. on centers	0.08– 0.15
2-in. fill	0.05– 0.08
Fill insulation over ceilings 4-in. fill	0.10– 0.16
Partitions, per square foot:	
Vertical board, battens both sides, stained; without studs	0.08– 0.12
Sheathed, both sides papered on cheesecloth; studs 2 by 4 in., 2 ft. on centers	0.20– 0.30
Lath and plaster, both sides papered; studs 2 by 4 in., 16 in. on centers	0.25– 0.35
Wainscot, stained, with wallboard or insulating board above not finished; studs 2 by 4 in., 16 in. on centers	0.15– 0.25
Floors, per square foot:	
Softwood; joists 2 by 10 in., 16 in. on centers, with bridging	0.15– 0.25
Softwood; joists 2 by 10 in., 16 in. on centers, with subfloor and bridging	0.20– 0.35
Hardwood; joists 2 by 10 in., 16 in. on centers, with subfloor and bridging	0.25– 0.50
Concrete, 4 in. thick, on fill, troweled surface	0.12– 0.20
Concrete; precast joists 3 by 8 in., 20 in. floor slab	0.20– 0.30
Roofs, per square foot:	
Wood shingle, on slats; rafters 2 by 6 in., 16 in. on centers	0.15– 0.22
Asphalt shingle, on sheathing; rafters 2 by 6 in., 16 in. on centers	0.15– 0.22
Roll roofing, 2 in. lap, on sheathing, rafters 2 by 6 in., 16 in. on centers	0.12– 0.17
Asbestos shingle, hexagonal or Dutch pattern: rafters 2 by 8 in., 16 in. on centers	0.22– 0.30
Slate or asbestos shingle, American patterns, on sheathing; rafters, 2 by 8 in., 16 in. on centers	0.25– 0.40
Steel, galvanized V-crimp, on sheathing; rafters 2 by 6 in., 16 in. on centers	0.15– 0.22
Tin, on sheathing; rafters 2 by 6 in., 16 in. on centers	0.20– 0.30
Built-up covering, on sheathing; rafters 2 by 8 in., 16 in. on centers	0.15– 0.30
Hips and valleys, galvanized-iron flashing, per linear foot of	0.40– 0.80
hip or valley	0.75– 1.25
Same, with copper, zinc, or lead flashing	0.25– 0.50
Same, flashed with roll roofing	0.40– 0.80
Roof cornice, with gutters and downspout	0.75– 1.25
Porch cornice and girder with gutter and downspout	

TABLE 4.—UNIT COSTS OF BUILDING OR REMODELING.—(*Continued*)

Item	Range of Cost
Windows, average size; with frames and trim complete in place, each	$8.00–16.00
Windows, cellar or attic	3.00– 5.00
Window screens, average size, each	1.50– 3.00
Doors, inside, average size, with frames and trim, complete in place, each	8.00–12.00
Doors, outside, average size; with frames and trim, complete in place each	12.00–25.00
Screen doors, average size, each	2.00– 6.00
Stairs, finished, per tread	2.50– 5.00
Stairs, cellar, per tread	0.50– 1.00
Kitchen cupboards, length of 8 ft., room height, with doors and drawers; complete in place, each	50.00–75.00
Kitchen cupboards, open shelf, each	18.00–25.00
Chimneys; with flue linings, per foot of height	2.25– 3.00
Extra flue, per foot of height	0.75– 1.00
Fireplace only, not including base or chimney	30.00–75.00
Fireplace base, southern conditions, no cellar	5.00–15.00
Fireplace base in cellar	20.00–35.00

To use the foregoing tabulation, first find the total amount required of each listed item, then multiply each amount by the corresponding unit cost, and finally add the products.

Example: A building addition 20 ft. square with piers and sills under three outside walls and one line of piers and sill through the center would have 4 by 20 or 80 linear ft. of foundation. This length of foundation having piers 2 ft. high and sills 6 by 8 in. should cost between $0.35 by 80 equals $28 and $0.55 by 80 equals $44, if all material and labor are bought. The lower figure would be used where materials and labor are relatively cheap, and the higher figures where materials and labor are relatively expensive. Miscellaneous expenses will add perhaps 10 per cent to the total of the listed items.

11. Cubing Method.—In securing the replacement cost of a set of existing buildings for purposes of financial record, for preliminary estimates, or for ordinary appraisal, a method known as *cubing* is used. The number of cubic feet of space enclosed by the building is multiplied by a per-cubic-foot cost. Empirical values for the per-cubic-foot cost of buildings have been used to date, but, if the variation in kind of building and quality of materials and workmanship and the differences in cost of materials and labor in different localities are all taken care of, the

list becomes long and the selection of the proper values very difficult. To make possible the determination of a per-cubic-foot cost that takes all these variations into account, a new method is here presented. A number of plans having accurate material lists were used in securing the information needed. The board feet of construction lumber, board feet of finish lumber, squares of roofing, cubic yards of aggregate, hours of carpenter labor, and the value of hardware, equipment, paint, and cement were obtained for each building. Each of these was divided by the cubic feet of space enclosed in the building. This gave the board feet of construction lumber, of finish lumber, fraction of a square of roofing, fraction of a yard of aggregate, hours of carpenter labor, and the value of hardware, equipment, paint, and cement per cubic foot of space in the building. By multiplying the board feet of dimension lumber needed per cubic foot by the price of dimension lumber in the locality, the board feet of finish

TABLE 5.—CLASSIFICATION OF BUILDINGS*

A. Two-story general-purpose barns, 55,000 cu. ft. capacity, concrete foundations, concrete floor in stalls, alleys, and bins

B. Hay and feeding barn, 64,000 cu. ft. capacity, post frame, concrete-pillar foundation, practically no steel equipment

C. Hay and feeding barn, 25,000 cu. ft. capacity, pole frame, no foundation. Pole-frame machine sheds

D. Two-story dairy barn, 58,000 cu. ft. capacity, concrete floor, steel stanchions, drop siding, balloon framing

E. Sheep sheds, machine sheds, and open sheds for cattle, 10,000 cu. ft. capacity, concrete foundation, single-wall siding, concrete floors in service alleys

F. Missouri-type poultry house, 30 by 30 ft., 10,000 cu. ft. capacity, concrete foundation, thin-section concrete floor

G. Double corn crib, 2,000 bu., 11,000 cu. ft. capacity, concrete floors and foundations

H. Granary, 2,000 bu., 3,000 cu. ft. capacity, concrete foundation and floor

I. Garage, one car, 2,200 cu. ft. capacity, concrete foundation and floor

J. Milkhouse, two room, 1,500 cu. ft. capacity, concrete foundation and floor

* For barns in classes *A*, *B*, *C*, and *D*, adjust cost unit for size as follows: For every 10 per cent increase in the cubical contents, decrease the unit cost by 2 per cent. Increase cost at a similar rate for smaller sizes.

For buildings in classes *E* to *J* adjust cost unit for size as follows: For every 10 per cent increase in the cubical contents, decrease the unit cost by 4 per cent, and for every 10 per cent decrease in the cubical content, increase the unit cost by 4 per cent. If a barn is in class *A* (with the exception that it is a pole frame without foundation), use the constants for poles and for miscellaneous that applies to this type of construction, and omit the constant in class *A* for sand and gravel.

lumber per cubic foot, the squares of roofing, the yards of gravel, and the hours of carpenter labor by the local price for each, and then adding all these products to the fixed cost of hardware, equipment, paint, and cement, the correct cost per cubic foot of the building for the locality is derived. Table 5 gives description of and classification for different kinds of buildings, and Table 6 gives the board feet, the squares of roofing, hours of labor, etc., per cubic foot for the different classes of buildings.

TABLE 6.—CONSTANTS TO BE MULTIPLIED BY PRICES TO DETERMINE COST PER CUBIC FOOT

Classification of buildings*	Construction lumber, board feet per cubic foot	Finish lumber, board feet per cubic foot	Roofing squares per cubic foot	Sand and gravel, cubic yards per cubic foot	Labor hours per cubic foot	Miscellaneous paint, cement, hardware, equipment, cents per cubic foot	Poles for pole-frame buildings per cubic foot
A	0.4100	0.0630	0.00079	0.0017	0.0190	0.0055	
B	0.3900	0.0340	0.00076	0.00082	0.0150	0.0027	
C	0.3900	0.0640	0.00087		0.0260	0.0001	0.00071
D	0.4900	0.0480	0.00066	0.0016	0.0210	0.0058	
E	0.4500	0.0260	0.0012	0.0013	0.0210	0.0040	
F	0.4400	0.1500	0.0012	0.0024	0.0260	0.0078	
G	0.5500	0.0160	0.00098	0.0033	0.0260	0.0111	
H	0.9000	0.3800	0.0015	0.0048	0.0500	0.0158	
I	0.4600	0.7200	0.0017	0.0038	0.0520	0.0127	
J	0.6100	1.0300	0.0019	0.0110	0.0600	0.0422	

* The appraiser can secure local prices on the following materials to represent each of the groups. Construction lumber will be represented by the price per board foot of a 2 by 4 in.—16 ft. of the grade used in the building; finish lumber by the price per board foot of a 1 by 8 in.—12 ft., *surfaced four sides;* roofing by the *price per square* of the particular kind of roofing used; sand and gravel by the average price of *sand and of rock or gravel per cubic yard;* labor by the average *hourly wage for a carpenter crew;* poles for pole frames by the cost of a pole *25 ft. long with a 6-in. top.* Since prices of nails, cement, paint, and equipment do not vary much from one community to another, the *total value* of these items per cubic foot of capacity in the barn is found, and this figure is added in to find the total cost of the building per cubic foot.

The application of the cubing method in determining the cost to build the combination horse barn and machine shed selected for the illustrative problem in Chap. II follows.

This building will probably be best suited to class *C* in Table 5 and Table 6 shows the constants to use in the computation. Using the following prices we can compute the cost per cubic foot for erecting the building. Dimensions lumber 6 cts. per foot board measure. Finish lumber 7½ cts. per foot board measure, roofing $6.50 per square, cost of poles $7.50 each and labor (average for crew) 75 cts. per hour.

Item of Cost	Constant	×	cost per unit	=	cost per cubic foot in the building
Construction lumber	0.390	×	$0.06	=	$0.023
Finish lumber	0.064	×	0.075	=	0.005
Roofing	0.00087	×	6.50	=	0.006
Poles for frame	0.00071	×	7.50	=	0.005
Labor	0.026	×	0.75	=	0.020
Miscellaneous				=	0.0001
Total cost per cubic foot				=	$0.0591

The building is smaller than the one used in the formula and the unit cost must be increased 2 per cent for each 10 per cent of additional capacity.

(25,200 − 24,400) ÷ 2,520 (10% of the Model building) = 0.31 of the 10% unit.

0.31 × 2% = 0.62 of 1% = the increase required.

$0.068 × 1.0062 = $0.0684 = the cost per cubic foot.

24,400 cu. ft. × $0.0684 = $1,668.96 = the cost of the building.

THE ANNUAL COST TO OWN THE BUILDING

Many times the farmer needs to know what it will cost to own the building each year. The items in this cost would be as follows:

	Per Cent
Depreciation (ave. for N.W.Mo.)	2.0
Interest on (½ new cost) @ 5%	2.5
Maintenance and repair	1.5
Insurance	0.5
Taxes	1.0
Cost to own as a per cent of new cost	7.5

$1,668.96 × .075 = $125.18 per year.

Questions and Problems

7. Estimate the cost of the poultry house selected for the problem used as an illustration in Chap. II.

8. Estimate the cost of the dairy barn used in the illustrative problem in Chap II.

9. What would be the first and the annual cost per hen and per cow in problems 7 and 8?

CHAPTER IV

APPRAISAL OF EXISTING BUILDINGS

The appraisal of a farm building consists of two steps: finding its present structural value and then determining its use value or its value to the farm on which it is located. A barn might have a certain structural value, but if the farm on which it is located has been reduced in size or if the soil has been depleted by erosion so that the barn is larger than is needed to house the animals and crops produced, then its structural value must be reduced in order to arrive at its actual value to the farm.

Many appraisers agree that the most reliable method of finding the structural value of an old building is to find the present cost of replacing the building and then depreciate this for use to date. The cubing method described in Chap. III is probably the best method to use in determining the replacement cost of an existing building. After the replacement cost has been found then the next step is to depreciate this value for past use.

In depreciating the replacement cost to determine present worth, the *straight-line method* is the one most generally used. This method is based on the assumption that the depreciation is the same each year from the time the building is completed, ready for use, until it is abandoned or junked. To find the percentage annual depreciation, it is necessary to know the date when the building was built and to estimate the remaining number of years the building will serve. Experience in the field with buildings of all ages, some new and some about ready to fail, soon enables the appraiser to fix the date of failure of a building.

The Equal-profits-ratio Method.—The straight-line method for depreciating building values is conceded to give an advantage to the buyer, especially in the earlier part of the life of the building. The *equal-profits-ratio* method[1] gives a value to a piece of property that provides equal profits to buyer and seller. This rule has

[1] Fish, J. C. L., "Engineering Economics," McGraw-Hill Book Company, Inc.

been adapted to depreciation of farm buildings and is shown in Fig. 1 as a curve plotted between percentage of new cost and percentage of useful life.

When it is known what percentage of the useful life of a building has been used, the curve in Fig. 1 shows the percentage of the

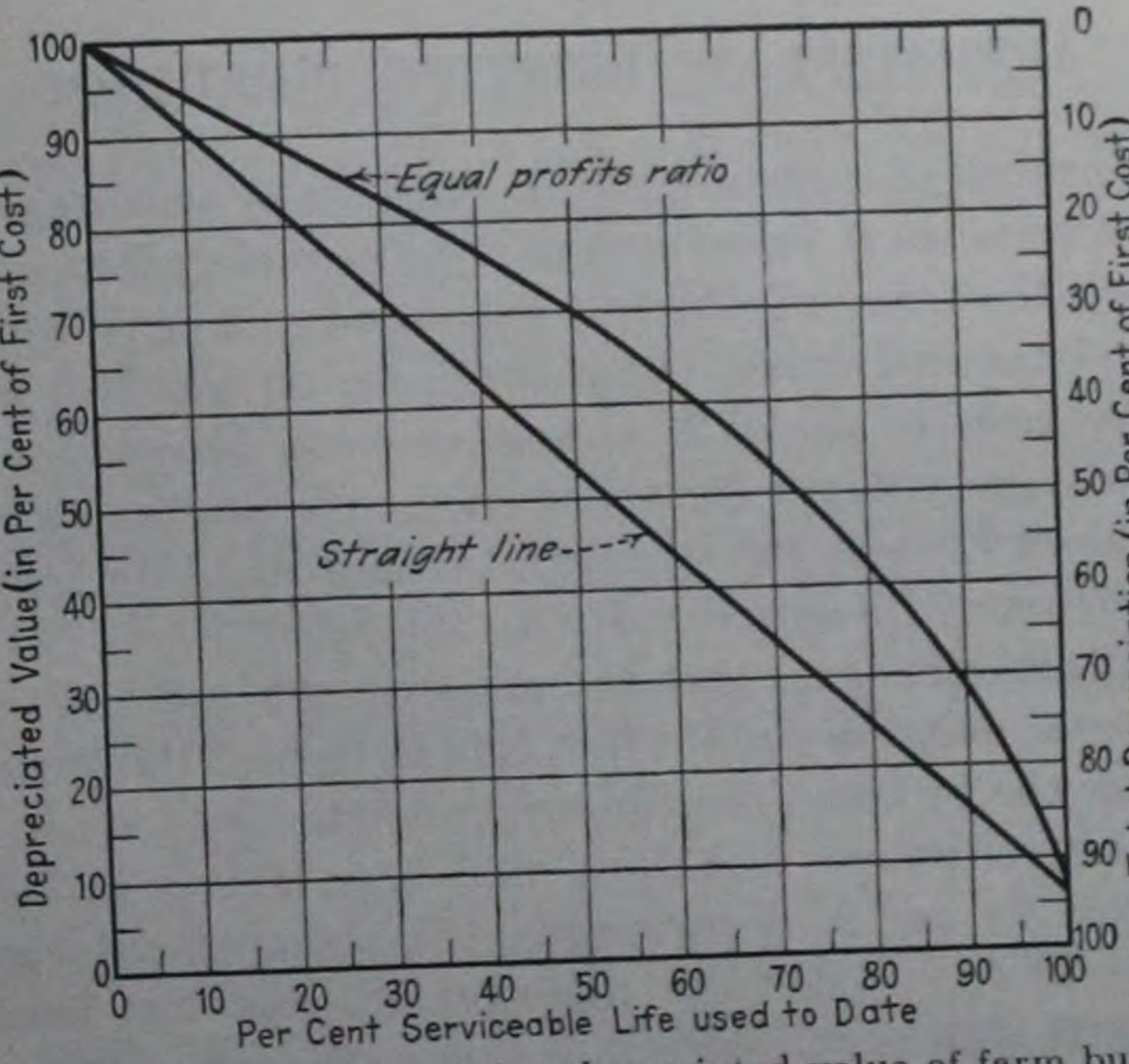


FIG. 1.—Curves for determining depreciated value of farm buildings.

new cost still remaining in the building so far as structural value is concerned.

Example: The replacement cost of a 20 by 20 Missouri-type poultry house is $226. This house has been in use for a period of 10 years, and the future serviceable life is estimated to be 40 years. This means that 20 per cent of the serviceable life has been used. By referring to Fig. 1, the present structural value by the straight-line curve is found to be 81 per cent of the replacement cost and by the equal profits ratio curve, 88½ per cent, or $183.06 and $200.01, respectively.

The present mechanical value of the buildings will be the appraised value if the buildings are 100 per cent useful to the farm. If they are only 50 per cent useful, then this present mechanical value must be reduced one-half.

To determine the percentage of usefulness of the buildings to the farm it is necessary to find the livestock carrying capacity and the building space required by this livestock.

By comparing this floor, hay, crib, and bin space *needed* to the storage and housing space in the building being appraised, the percentage usefulness of the building can be derived.

To determine the percentage usefulness of the structure, it is necessary to weigh the different parts of the barn according to their respective values. Since the stall space has more value than hay and grain spaces, it will be necessary to give more credit to it than would be given on a cubic-foot basis. The following weights have been selected for the different parts of the barn when percentage usefulness is being figured: stall or pen space, 5; hay space, 3; and grain storage space, 1. This percentage usefulness, times the structural value previously obtained, plus or minus the profit or loss resulting from changing the building to meet the requirements gives the appraised value of the building.

If a building were too large, it might be possible that the lumber salvaged in making a reduction of it would more than pay the costs of making the change. Usually, however, the expense in making the change is greater than the value of extra materials obtained, and a deduction must be made to arrive at the appraised value to the farm. If the building can be used completely as it is, the structural value and the appraised value will be the same.

Example: The correct land use on a farm calls for 12 dairy cows, 4 horses, 2 brood sows, and 500 hens. The general-purpose barn on the farm has a structural value of $630. It has stalls for 6 cows, 6 horses, 35 tons of hay, and 200 bu. of corn.

The 6 horse stalls could be changed into cow stalls for $150. This would make the barn 100 per cent useful so far as stalls are concerned. The 12 cows would need 15 tons of hay. (See Table 3, p. 16.) The barn would be 15 divided by 35, or 43 per cent useful so far as hay storage is concerned. Since the need for corn is more than the capacity of the crib, the barn would be 100 per cent useful so far as crib space is concerned.

To find the weighted average usefulness, we have

Stalls,	100 per cent	× 5	= 500
Hay,	43	× 3	= 129
Corn,	100	× 1	= 100
		9	= 729

$729 \div 9 = 81$ per cent

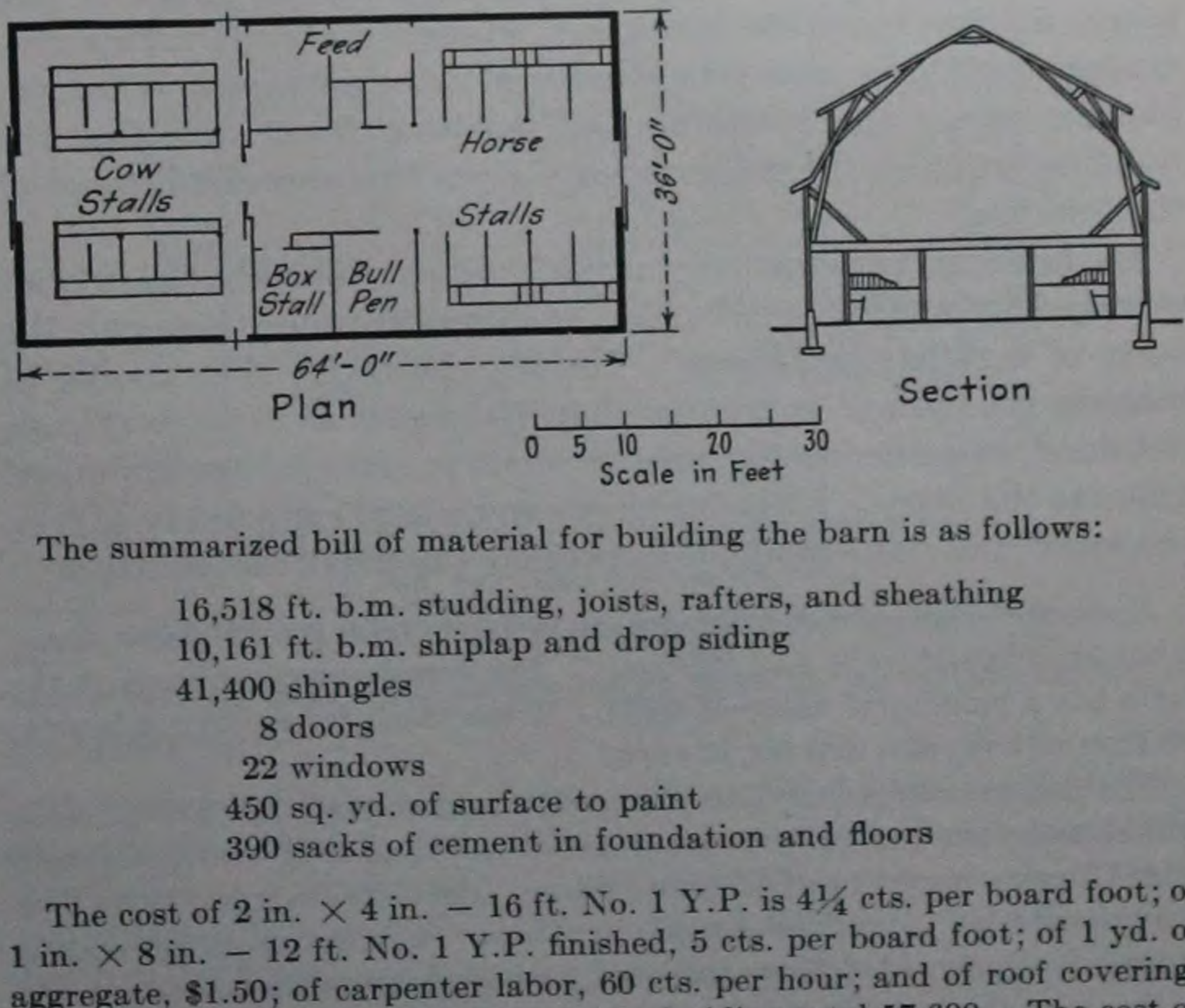
The structural present worth $630 times 81 per cent, the percentage usefulness of the building, gives $510.30, the present worth to the farm

if no changes were needed. By subtracting the $150 that must be spent in making changes, we have $360.30, the actual value of the building to the farm.

Questions and Problems

10. The dairy barn shown below is 22 years old and is located on an 80-acre farm in an area having Grundy-type soil on the 49 acres of cropland and Lindley soil on the 26 acres of pasture. There are 5 acres in the farmstead. Dairying is the principal enterprise. One work team and 50 hens make up the other enterprises requiring land.

Following is a floor plan and sectional view of the barn:



The summarized bill of material for building the barn is as follows:

16,518 ft. b.m. studding, joists, rafters, and sheathing
10,161 ft. b.m. shiplap and drop siding
41,400 shingles
8 doors
22 windows
450 sq. yd. of surface to paint
390 sacks of cement in foundation and floors

The cost of 2 in. × 4 in. — 16 ft. No. 1 Y.P. is 4¼ cts. per board foot; of 1 in. × 8 in. — 12 ft. No. 1 Y.P. finished, 5 cts. per board foot; of 1 yd. of aggregate, $1.50; of carpenter labor, 60 cts. per hour; and of roof covering, $4.50 per square. The cubic feet in the buiding total 57,600. The cost of the materials needed to build the barn is $1,848.60.

a. Determine the replacement cost of the barn by the labor-plus-material-cost method.

b. By the material-cost-plus-a-percentage-for-erection method.

c. By the cubing method.

11. Depreciate the replacement cost found by cubing, using the equal-profits-ratio curve to find the present structural value.

12. Find the livestock-carrying capacity for the farm, the percentage usefulness of the present building, and its value to the farm.

CHAPTER V

THE OPTIMUM INVESTMENT FOR BUILDINGS

The buildings necessary to house any enterprise must be paid for out of the income from that enterprise if desirable economic relationships are to be maintained. It is sometimes difficult to measure this income because some of the benefits are in intangible form that do not show directly in the cash ledger. Many times an investment is considered to be desirable when it will make work more enjoyable or when it will decrease the time and physical energy required to carry out the daily routine. Efficient buildings and yards often make the work of handling livestock more satisfactory and less hazardous. They may save time and enable the farmer to enjoy some recreation or to give more thought to planning and management. They may be the means of making the farm a better place to live and work, and this makes farming a more desirable occupation. Caring for livestock with the bare essentials in buildings, gates, and fences requires more energy on the part of the farmer and often subjects him to uncertainty and worry. If he has good buildings and barns he can plan to do his field work, conscious of the fact that his livestock will not be likely to require his attention and interrupt his work. These thoughts are not presented to make a case for larger investment in buildings but to bring out the fact that there are intangible benefits that are sometimes worthy of consideration.

Many of the building studies made in the past have made the appraised value of the buildings the basis for decisions as to the contribution of buildings to the farming business. If future studies can be based on the quality of service rendered as well as mechanical value then the results will show the value of good housing or the lack of value as the case may be. Many buildings fall far short of maintaining the environment needed by the livestock housed, and thus we have but limited knowledge of the contribution that is possible from buildings that furnish a desirable environment at all times.

12. Farms are equipped with buildings with one of three standards in mind—*minimum*, *optimum*, or *luxury standards*. Minimum standards provide bare necessities. Optimum standards provide for efficiency, for the maintenance of accepted environment for different animals and fowl. Individualistic or luxury standards may be as good as or better than the other standards. They usually represent some special idea of the individual from which he secures sufficient satisfaction to warrant the extra investment. Any such investment should be made by the farmer with a full understanding that he or his estate will likely be required to pay the bill. When the farm is sold eventually the buyer in most cases will not be willing to pay for anything above the optimum standard.

METHODS OF APPROACH TO THE PROBLEM OF INVESTMENT IN BUILDING EQUIPMENT

13. Studies covering a considerable period of time have been made by the Agricultural Economics Department of the Minnesota State College on this subject. The plan followed in these studies was to set aside all the items of cost of operating an enterprise except labor and shelter. Then by assuming a rate for labor the residual for buildings was obtained. The data are for one cow and the young stock that go along with her; that is, the cost and returns for the entire dairy herd have been divided by the number of cows. Costs listed represent cash outlay and farm products at their marketable value. Returns include cash sales plus products used in the home and by other enterprises at their marketable value. Data from this study are given in Tables 7 and 8.

This study covers a period when prices were low to average, and therefore the results secured can be depended upon as being conservative. The study points out the fact that good housing is wasted on low-producing animals or, stating it in another way, low-producing cows will not pay for their feed, care, and shelter.

When the labor rate has been decided upon the amount of money available for rent, or cost of shelter for the year can be obtained. This annual rent can then be translated into the building investment it will support. Summaries of building-cost studies and farm records show the following to be reasonable

TABLE 7.—AVERAGE ANNUAL COSTS AND RETURNS FOR DAIRY CATTLE, 1932–1943
(Per Cow Basis)

Items	All herds	High-producing herds	Low-producing herds
Pounds butterfat per cow	232	299	175
Man-hours per cow	157	191	140
Costs:			
Feed	$64.64	$76.41	$55.16
Horse work	0.66	0.72	0.63
Equipment	4.58	6.48	3.31
Interest on cattle	4.47	5.38	4.26
Veterinary, testing, etc	2.21	3.99	1.33
Total	$76.56	$92.98	$64.69
Manure credit	5.95	6.90	5.15
Net	$70.61	$86.08	$59.54
Value produced:			
Dairy products	86.30	115.94	63.54
Animals	36.24	40.82	31.29
Total	$122.54	$156.76	$94.83
Residual to labor and shelter	$ 51.93	$ 70.68	$35.29
Residual to shelter with labor at 20 cts. per hour	20.53	32.48	7.29
at 25 cts. per hour	12.68	22.93	0.29
at 30 cts. per hour	4.83	13.38	0.00

Costs and returns for entire dairy herd divided by the number of cows.

TABLE 8.—POSSIBLE INVESTMENTS IN DAIRY BUILDINGS WITH DIFFERENT LEVELS OF PRODUCTION AND DIFFERENT RATES OF RETURN TO LABOR

	All herds	High-producing herds	Low-producing herds
Investment per cow			
With labor at 20 cts. per hour	$257	$406	$91
25 cts	158	287	4
30 cts	60	167	0
Investment for 15-cow herd			
With labor at 20 cts. per hour	$3,855	$6,090	$1,365
25 cts	2,370	4,305	60
30 cts	900	2,505	0

estimates of annual dairy building costs in Minnesota, expressed as a percentage of the original cost.

	Per Cent
Depreciation	2.5
Maintenance and repairs	1.2
Interest (5% on the average value for the life of the building)	2.5
Insurance	0.5
Taxes	1.3
Per cent of first cost to own dairy buildings	8.0

By dividing the annual rent available by the per cent of the total cost to own the building one year the investment that such rent would justify is obtained.

TABLE 9.—AVERAGE ANNUAL COSTS AND RETURNS FOR LAYING FLOCK, 1935–1943
(Per Hen Basis)

	All flocks	High-producing flocks	Low-producing flocks
Eggs per hen	136	172	99
Man-hours per hen	2.8	2.7	2.8
Costs:			
Feed	$1.85	$1.90	$1.88
Equipment	0.17	0.17	0.20
Interest	0.04	0.04	0.04
Miscellaneous	0.13	0.13	0.16
Total	$2.19	$2.24	$2.28
Manure credit	0.09	0.10	0.09
Net	$2.10	$2.14	$2.21
Value produced:			
Eggs	2.47	3.11	1.82
Poultry	0.66	0.74	0.58
Total	$3.13	$3.85	$2.40
Residual to labor and shelter	$1.03	$1.71	$0.19
Residual to shelter with labor at 20 cts. per hour	$0.47	$1.17	$0.00
25 cts. per hour	0.33	1.03	0.00
30 cts. per hour	0.19	0.90	0.00
40 cts. per hour	0.00	0.63	0.00

The same type of analysis applied to poultry buildings is shown in Table 10.

TABLE 10.—POSSIBLE INVESTMENT IN POULTRY SHELTER WITH DIFFERENT LEVELS OF PRODUCTION AND DIFFERENT RATES OF RETURN TO LABOR

	All flocks	High-producing flocks	Low-producing flocks
	Investment per hen		
With labor at 20 cts. per hour	$5.23	$13.00	$0.00
25 cts. per hour	3.67	11.45	0.00
30 cts. per hour	2.11	10.00	0.00
40 cts. per hour	0.00	8.76	0.00

Residual from Table (10) capitalized at 9% with annual charges as follows:

	Per cent
Depreciation	3.0
Maintenance and repairs	1.5
Interest at 5% on average valuation	2.5
Insurance	0.5
Taxes	1.5
Total	9.0

14. A different approach to the problem of determining the optimum investment in buildings is presented by D. H. Doane. His plan is based on the idea that the amount that can be spent for housing any enterprise depends upon the annual return from it and, of course, upon the response of the project. To determine the percentage of income that could logically be spent for housing, Mr. Doane sent a questionnaire to a number of farmers, farm managers, and buildings specialists, and the percentages given are the average of their opinions. His figures on annual building cost as a percentage of first cost are somewhat higher than have been found in other studies, which makes the results on the conservative side. If the annual income for an enterprise is higher than the average given, it can be used instead of his average figure to determine the amount of investment that could be made for the particular enterprise. The annual income, times the per cent allowable for housing, divided by the per cent the annual is of the first cost of buildings, gives the allowable investment. Table 11 gives data for different farm enterprises.

TABLE 11.—BUILDING INVESTMENT PER UNIT OF LIVESTOCK

Kind of livestock	Average annual income per unit	Percentage of annual income that can be spent for buildings	Annual building cost as percentage of first cost	Allowable investment in buildings
Dairy cow	109.43	10.7	8.7	134.57
Grade beef cow	24.32	8.7	8.0	26.44
Brood sow	45.00	6.7	9.0	33.50
Ewe	7.20	7.7	8.0	6.93
Hen	2.00	9.0	9.7	1.85

THE FARMERS' ANSWER

15. In the conduct of his business the farmer has been forced to answer this question of how much he should invest. No doubt, his answer has been influenced as much by availability of cash or credit as by his best judgment. The amount he has invested represents, in most cases, the minimum requirement. Farmers in Northwest Missouri have invested as shown in Table 12.

TABLE 12.—INVESTMENT IN SERVICE BUILDINGS PER ANIMAL

Kind of livestock	Average for all farms	Range, all farms	Annual building cost per animal
Work stock	$95.00	$14.47 to $291.65	$7.16
Dairy cows	108.13	11.08 to 315.96	8.14
Stock cattle	39.90	3.54 to 158.75	3.01
Brood sows	24.47	1.00 to 96.80	1.84
Stock hogs	7.25	0.35 to 26.80	0.55
Poultry	1.68	0.28 to 5.73	0.13
Sheep	10.87	0.54 to 31.38	0.81

ANNUAL COST OF BUILDINGS

16. In any going concern, annual costs are the important point for consideration. If an enterprise is untried or definitely temporary in nature then the total investment must be guarded very carefully. Many times the first cost of a barn, which is almost as essential to the operation of the farm as the land itself,

is overemphasized. In case of such an investment the annual cost is of greater importance than first cost.

In the study of northwest Missouri farms, all costs for operating the farm were grouped as follows:

TABLE 13.—ITEMS IN FARM OPERATING COST ON 200 NORTHWEST MISSOURI FARMS

Item	Annual cost	Per cent of total
Feed fed	$3166.00	73.7
Interest on animals	223.00	5.2
Labor	583.00	13.5
Fences	60.00	1.4
Service buildings	245.00	5.7
Insurance and veterinarian fees	17.00	0.5
Farm operating cost, average	4294.00	100.00

Buildings are one of the smaller items of cost on these farms so long as they are used. If a building is not used the $245 cost must be met just the same and may then become an item of greater importance.

Questions and Problems

13. In what different ways may buildings bring a return on the investment in them?

14. What standard of building usually interests the absentee owner? Why?

15. Account for the fact that we have three standards.

16. If dairy cows produce 6000 lb. of milk per year, what would be a fair investment in buildings for them according to (*a*) the Minnesota Study? (*b*) the Doane method with milk selling for $2.85 per hundred (use Minnesota Data) (*c*) standards in Northwest Missouri?

17. If hens produce 200 eggs per year with eggs at 26 cts. per dozen, what investment in a poultry house would be justified?

Reference

ASHBY, WALLACE: What's Happening to Farm Buildings? *Agr. Eng. J.*, Vol. 26, No. 3, p. 101, March, 1944.

CHAPTER VI

FIELD AND FARMSTEAD PLANNING

A growing interest in soil conservation, development of equipment for efficiency in doing farm work, the rerouting of highways, and an increasing appreciation of the country as a place to live are responsible, in part, for the widespread interest in farm and farmstead planning. Many men in the U.S. Soil Conservation Service and in extension work are devoting considerable time to schools and conferences with farmers on this problem. No attempt will be made to discuss farm layout here except as it has an influence on the location and grouping of the buildings on the farmstead. An unfortunate location of the present building group is one of many conditions that makes the replanning of farms and farmsteads difficult.

17. Factors to Be Considered in Locating the Farmstead.—When the building group is poorly located, it is very difficult to plan the farm for proper management of runoff water, for efficiency in doing the farm work, or for accessibility to markets, school, etc. Most of the building groups were developed according to no particular plan or were located and arranged in pioneer days when the conditions and needs were very different from those of today. The early settler did not have the equipment or the time to drill a well or plant a windbreak. His first interest was in getting out logs and building a home. Since a supply of water was necessary at once, the location for the homesite was made near a spring or running stream and in a well-protected area in the woods.

Accessibility to the highway was not important to this early settler, because all roads were of the same quality as the one leading through the woods to his home. He had little traveling to do, and when he did make a trip to town the kind of vehicle and the amount of load was limited as much by the main road as by his private drive.

Today a network of all-weather roads reaches a large percentage of farms. If the farmstead is located on the highway or if

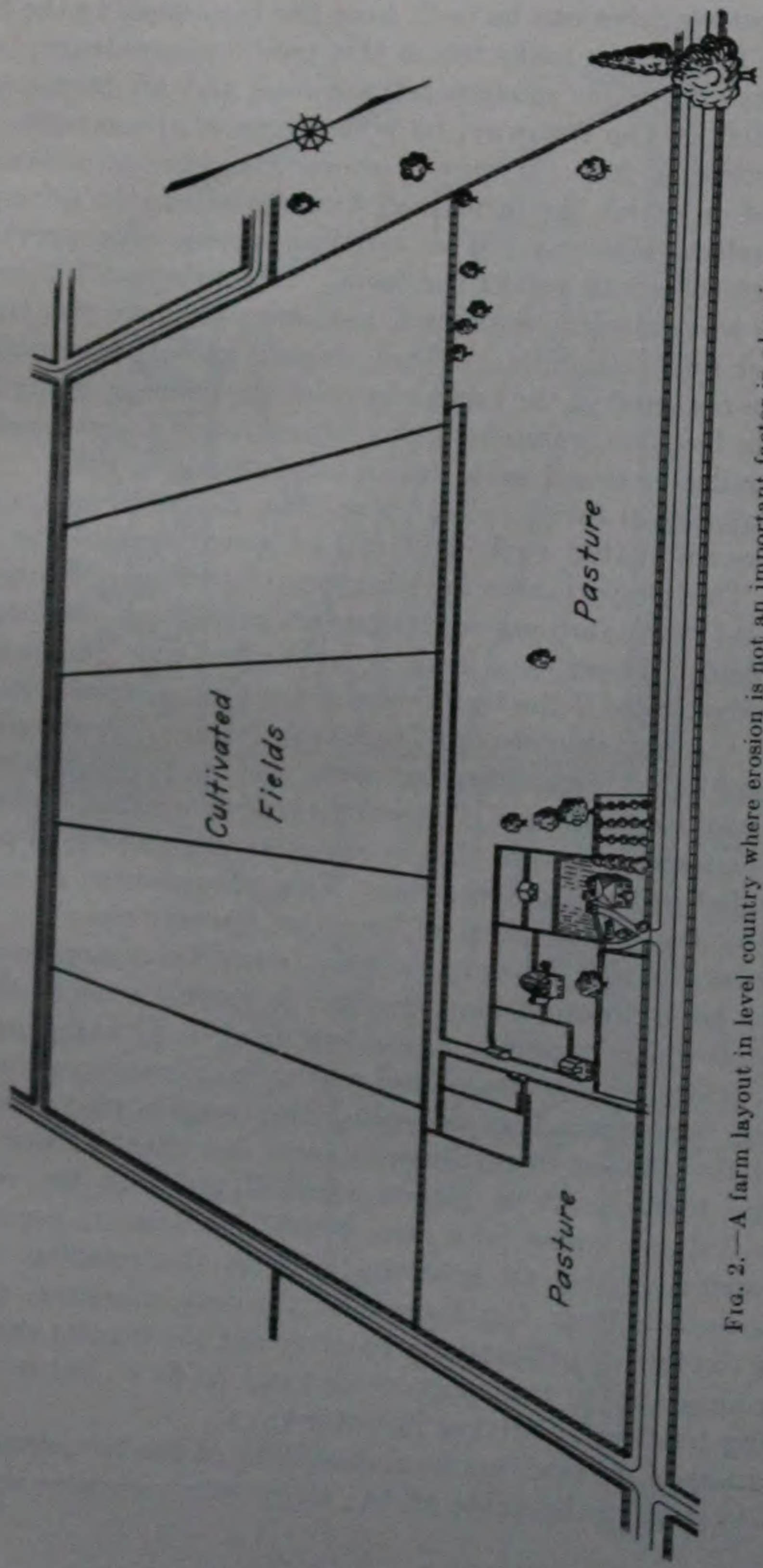


FIG. 2.—A farm layout in level country where erosion is not an important factor in planning.

an all-weather drive can be built from the farmstead to the highway, the farmer can make use of this public convenience; but if he cannot afford this modern private road and his farmstead is not located on the highway, he is deprived of the benefits that should come to him. Figure 2 shows the plan of a farm on level land on which the farmstead was moved to take advantage of a modern highway. The building group was previously located at the south end of the farm. The principal business of the farm was dairying, and it was necessary to make two trips to town each day with milk. School, church, and other community activities centered in the town were also the cause of many trips. The new location eliminates any travel over a dirt road and saves 2 miles of travel each time a trip is made to town.

Accessibility to Fields.—This plan (Fig. 2) shows long, narrow fields placed so that each field will be convenient to the farmstead. This shape makes for efficiency in the use of equipment, since most of the farming operations are carried out the long way of the field. These long fields require more rods of fence than would be required if the farm were laid out in an equal number of squares. A portable electric fence may be used for the division lines and the few additional rods will not be a factor of importance in planning. The service lane connects all fields with the farmstead, a feature that is essential when 1 year of pasture is included in the crop rotation. This arrangement is convenient, also, for the removal of crops at harvest time.

Contour Farming.—Comparatively few farms are on level land and can be laid out without thought to conservation of the soil. Farms on which erosion is a problem must be arranged not only for efficiency but for proper soil and crop management, contour farming, and terracing as well. This means that the fields cannot be laid out in rectangular form but that division fences between fields must be placed approximately on the contour. Figure 3 shows a plan for a farm which is laid out to permit contour operations on all fields included in the rotation. Fields are accessible from the farmstead through a central pasture, giving the farmer opportunity to carry out the regular operations of farming and to transport crops from fields to barns without crossing terraces or driving in waterways.

Drainage.—In addition to accessibility of the farmstead to the highway and to the fields on the farm, other features should be

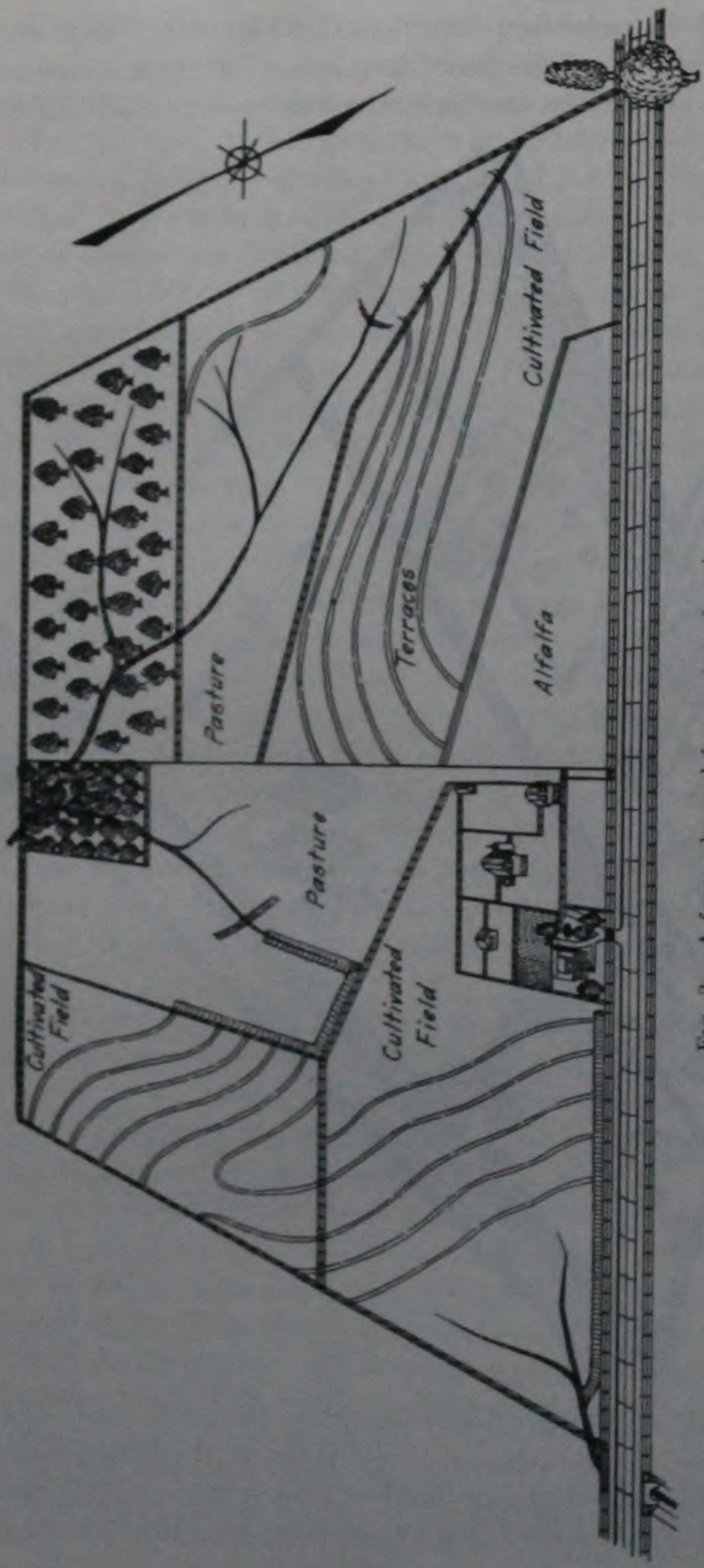


FIG. 3.—A farm planned for contour farming.

considered in selecting the location for the building group. Drainage is one of the more important of these considerations. Healthful conditions are much more easily maintained about

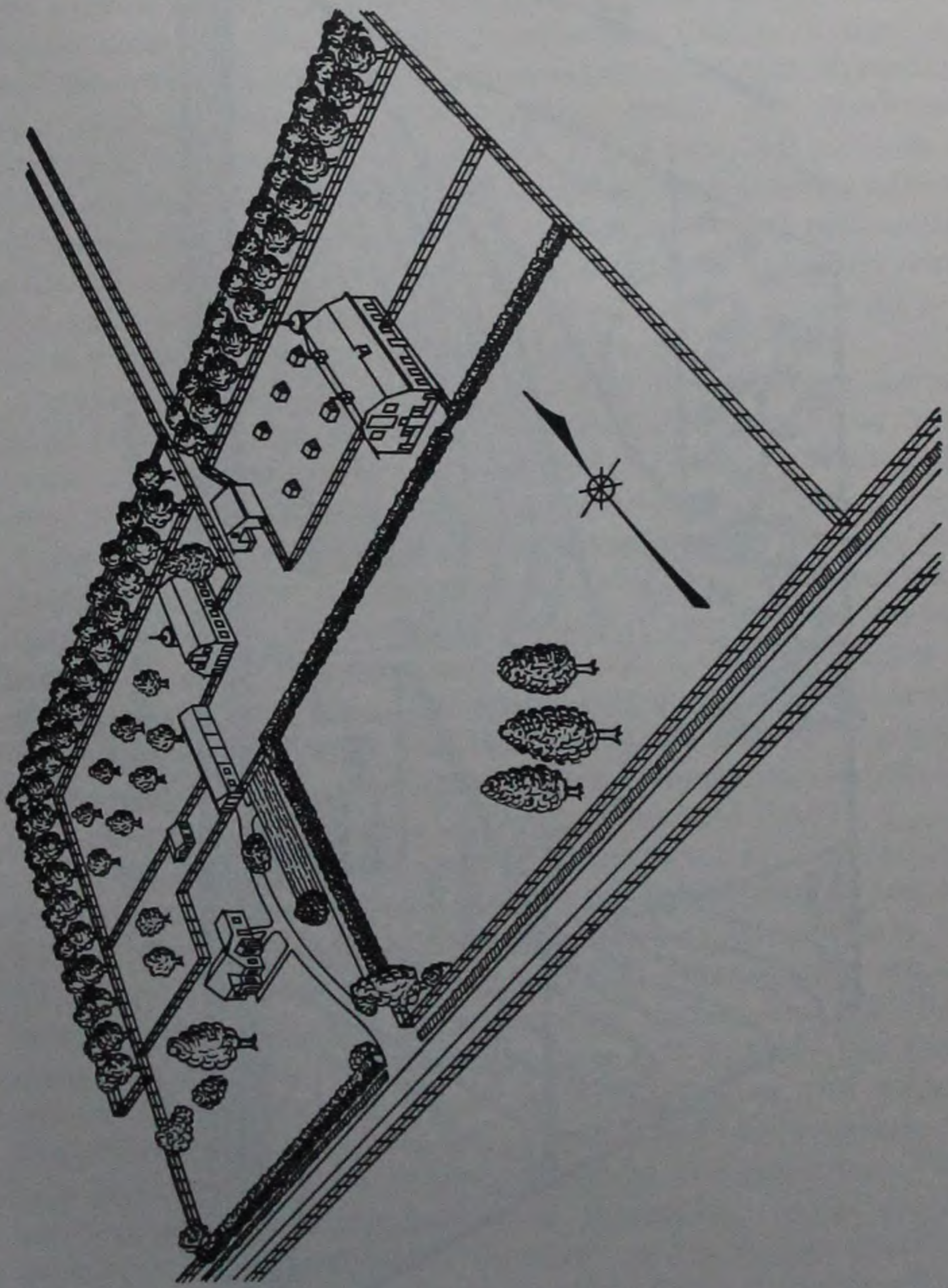


FIG. 4.—General farm with south front.

yards and buildings where surplus water is not allowed to accumulate. A southeast slope is very desirable, because, in addition to good drainage, such a slope makes better use of sunshine and gives some protection from the northwest winds of

winter. If good natural drainage is not available, much can be done to improve conditions by grading up around individual buildings and by use of underground drains or protected surface gutters. In any case, buildings should be spouted and the downspouts connected to underdrains or protected surface gutters.

The *outlook* or view from different locations is worthy of consideration in selecting a building site. Mount Vernon is famous because it was George Washington's home, but it would be exceptional also because of the wonderful views that are available up and down the Potomac River. There are few farms in the country that will not furnish one or more interesting views. It may be the rolling, timbered hills that provide varied color combinations from season to season; it may be the distant village or the highway with all its activity; or it may be a lake or stream. Whatever the view is, it is worth considering for the interest and enjoyment it will furnish the farm family.

18. Arranging Buildings on the Farmstead.—In many parts of the Old World, farm buildings, including the dwelling, are grouped to form three sides of a square. The central court enclosed is often paved, and the well is located in the center. This arrangement is probably carried over from the days of feudalism, when it was necessary for the followers of one lord or baron to rush all belongings into the court in case of an attack. Laborers were plentiful, and the premises could be kept clean, although it is doubtful if modern standards of sanitation were maintained.

Central Service Court.—In America there is less uniformity in arranging buildings, although a few arrangements are common to many farmsteads. The central service yard or court, although not so well defined and standardized as it is in European countries, is still the center or basis from which the work of the farm is carried on and from which the various buildings are located. The central service yard need not be of any particular shape or size, but it should be wide enough so that trucks or loaded wagons can be turned easily, thus facilitating the work that must be done around the building group. It should be possible to reach each service building from this court without opening gates or going through yards where stock is kept.

The lane leading to the fields, as well as the one leading to the highway, should have its beginning in this service court. The

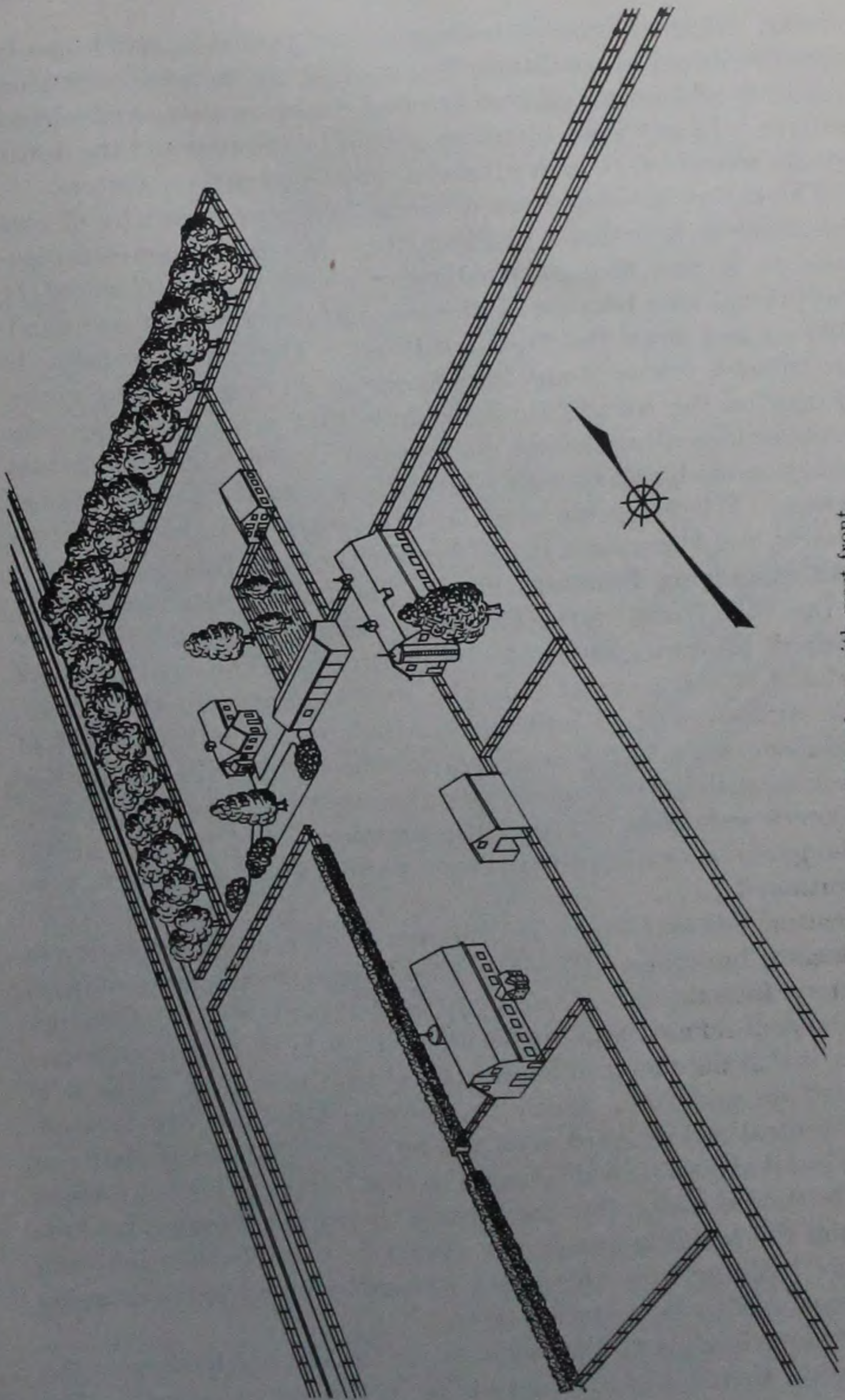


FIG. 5.—Dairy farm with west front.

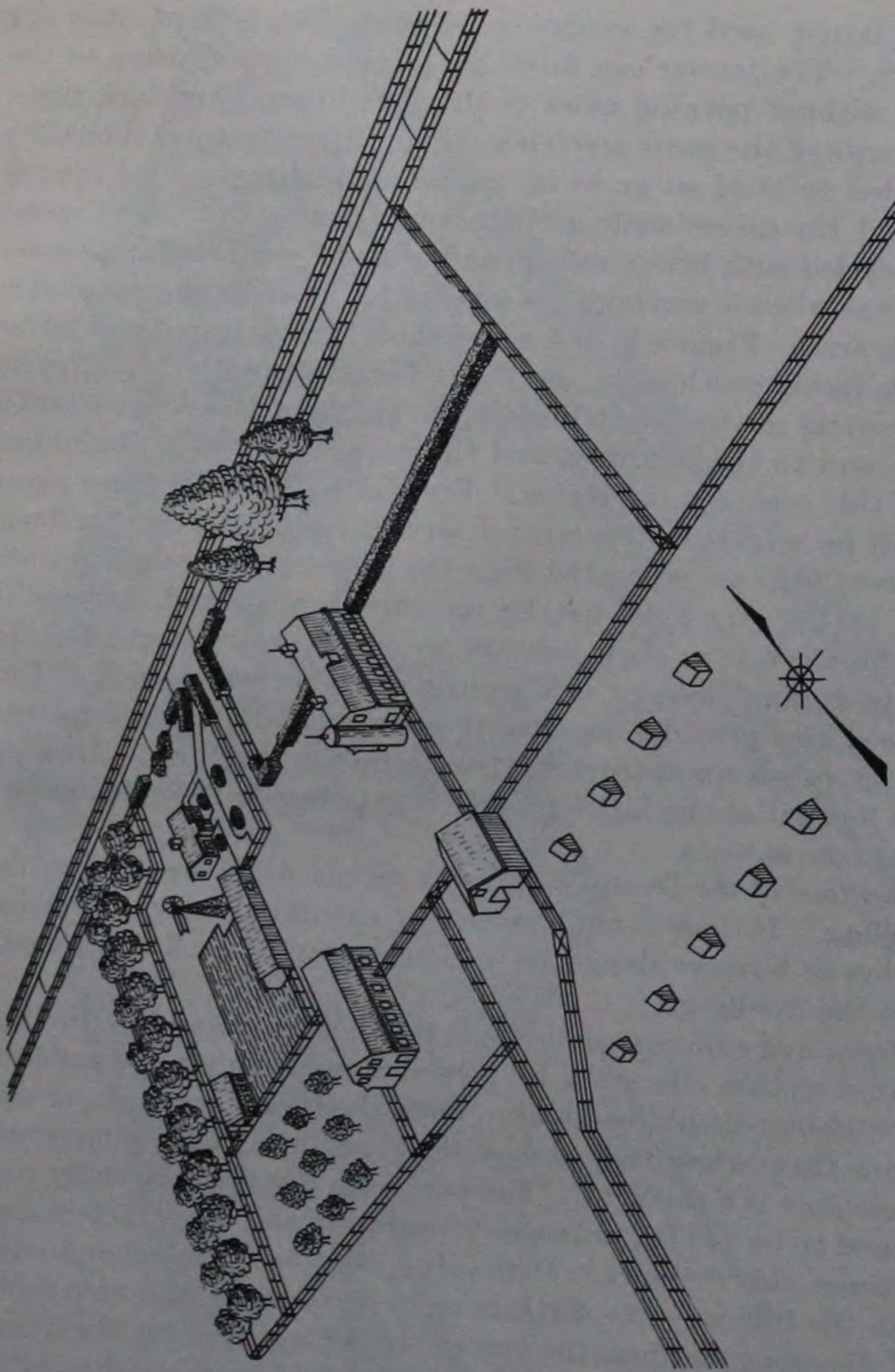


FIG. 6.—General farm with north front.

court is not used for confining livestock but is kept open for service. The farmer can hitch his teams here and drive to the fields without opening gates or driving through livestock pens. The parts of the court receiving the most frequent use should be graveled or oiled so as to be usable at all times. One farmer covered his drives with asphalt-bound macadam.[1] The stone was leveled with heavy rollers, and after 11 years' use is as good as it was when it was laid. A good sod is ideal for the remainder of this area. Figures 3, 4, 5, and 6 show typical layouts for farmsteads facing south, west, north, and east, respectively. Notice the central service court in each of the plans, the connection to fields and to the highway, and the accessibility of all buildings from this central service area. From observation of these plans it will be seen that the central service court and the buildings adjacent to it are separated from the highway by a small grassed area. This area need not be considered wasteland, because it can be used as a show pasture to advertise livestock, for the handy saddle horse, or as a night pasture for work stock. This grassed area provides an attractive foreground for the farmstead and gives an unobstructed view from the dwelling. An auto pass located at the highway with a gate beside it for teams is a great convenience.

Location of the Dwelling.—Water should drain away from the dwelling. If there is not satisfactory natural drainage, diversion ditches or terraces should be laid out to carry runoff water away from the dwelling.

Prevailing summer winds must be considered and the dwelling located so that odors will be carried away from it. Distance to the highway should be greater when the fronts are south or east fronts than when they are west or north. This is important where dust is a problem. The minimum distance is usually considered to be 125 ft., although topography and other factors may influence this distance. If the dwelling site is on higher ground than the highway the distance may be reduced, and vice versa.

Interesting and beautiful views should be saved for the living-room windows. No building or tree should be allowed to interfere with this view. The kitchen window should command a view of the central court and of each building, if possible. This enables the housewife to know when the men have come in from

[1] *Capper's Farmer*, February, 1941, p. 6.

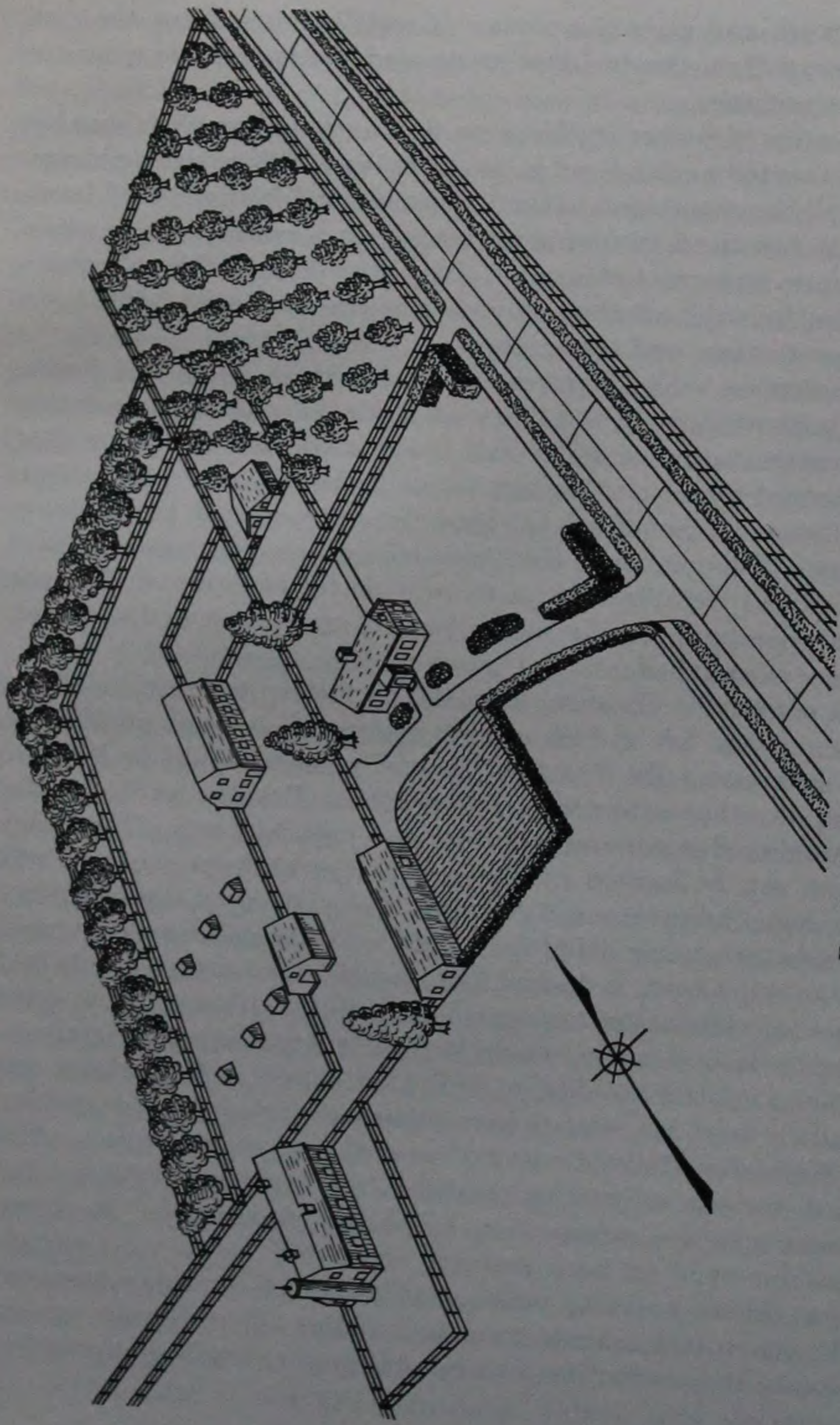


FIG. 7.—Beef-cattle farm with east front.

field work and gives her a view of each building when the men are away from the building group and she is the sole guardian of the premises.

Location of Service Buildings on the Court.—There are a number of factors to be considered in the grouping of the service buildings. Not all the requirements can be met in ideal fashion on all farmsteads, but the final plan must usually be a compromise in which the more important things are given precedence. These requirements, in order of their importance, are sanitation, efficiency, fire protection, and appearance.

Sanitation.—The maintenance of health in herds and flocks, the improvement in salability of products, and the prevention of contamination of water and food for the family require that important attention be given to sanitation about the farmstead. Sanitation is promoted by good drainage around the building group. This subject has been discussed previously. Good fences and well-planned yards provide for isolation of different enterprises and usually aid in preventing disease or its spread, if once introduced.

A reasonable distance, from 100 to 150 ft., between buildings is necessary for success where enterprises require a different environment. For example, the dairy barn should be isolated from all other enterprises on the farm. Exercise yards for the cows should not be adjacent to the milking barn. The milkhouse can be located on the central court where livestock will not have access to it. See Fig. 5 for such an arrangement. Beef cattle, young dairy stock, and work animals may be housed in the same barn, if desired, but should have separate yards and pens for satisfactory management. Hogs, although often combined with beef cattle, should be provided with separate quarters, either a central building or individual houses. Both sheep and poultry must be isolated from other enterprises for best results.

Well-painted buildings aid in problems of sanitation. The hard, waterproof coating resulting from paint on buildings and fences makes a surface that keeps the lumber dry. Rain and sunshine tend to keep surfaces clean and sanitary. Concrete floors, clean watering places, and protected sunshine areas are all aids in encouraging growth, building up resistance against disease, and preventing disease—or, in other words, in promoting sanitation.

Efficiency.—A study of the different tasks that must be done, the number of times they must be repeated, the time of day when they must be carried out, and the amount of energy that must be expended in doing them will often lead to ways and means of reducing time and energy required in completing these tasks and secure the highest efficiency for the building group as a working unit. If the dairy enterprise is important on the farm, it will usually be found to require the greatest number of chore hours, done, for the most part, early in the morning and late in the evening. Light and water requirements are large as compared to those of many other enterprises. These facts would necessitate locating the dairy barn as close to the dwelling as feasible. The poultry enterprise, also, needs frequent attention, requires considerable use of light, and uses a limited amount of water. In some localities placing the poultry houses near the dwelling is also influenced by the need for protection of the flock from thieves.

Most of the other enterprises do not require so much chore labor as does the dairy, and the need for attention during early and late hours comes only at irregular intervals. There is not the need for clean surroundings that we find in the dairy enterprise, where food for human consumption is being handled in its final form. For these reasons the buildings to house these other enterprises can, if desired, be placed at greater distance from the dwelling than would be desirable for the dairy barn.

Manufacturers give a great deal of attention to efficiency of arrangement in their plants. Each step in the process of manufacturing is studied to find ways and means of saving time and energy. A certain factory that was supposed to be well organized found, through the work of an efficiency engineer, that 60 per cent of its wages was being paid for walking. Reduction of this waste by rearrangement no doubt saved the company a considerable sum of money each year. The work of the farmer is more varied, permitting less standardization than the work of the factory; nevertheless, efficiency can be increased by planned arrangement.

The efficiency of two comparable Wisconsin farmsteads was studied. It was found that in doing similar work through the day the operator of one farm walked 4,140 ft., whereas the operator of the better arranged farmstead walked only 3,240 ft.

This is a saving of 900 ft. per day, or 62 miles per year, through better arrangement alone.[1]

For *protection from fire* the buildings should be separated by at least 100 ft. If small structures are placed between the major buildings, these structures should be made of fireproof materials. In case a fire occurs at a time when there is a high wind, it may be very difficult to prevent its spread, even though there is a considerable distance between buildings. Chemical fire extinguishers placed at strategic points will help greatly in controlling fires at their beginning. A community fire company owning a truck fitted with chemical equipment, a pump, and a hose can do much toward reducing damage from farm fires. For this organization to be effective, a large cistern must be kept full of water on each farm. The cistern should be located as near the center of the building group as possible.

A great majority of farm fires are started by lightning striking unrodded or poorly rodded buildings. No evidence is available to show that a building that was properly rodded and grounded has ever burned as a result of being struck by lightning.[2]

Appearance.—The modern farmer and his family travel much more than did the pioneer farmer and his family. They see other farmsteads and get ideas that can be used at home, and it becomes a matter of pride with them to keep up the appearance of their own farmstead. The appearance of the farmstead is dependent to a great extent on landscaping and care, but it can be improved materially by giving thought to it when buildings are being located. The modern farmhouse does not have the height and size of the homes of the past century, which were built to house large families and possibly several hired men. For that reason the house no longer forms a good balance for one of the major service buildings, and it seems advisable to consider it as a separate unit from the service group. Two major service buildings now form the basis for balancing up the service group independent from the dwelling. Roof covering gives longer service on buildings having their main axis extending north and

[1] Grubb, P. E., Cutting Labor Costs by Efficient Planning of Farm Buildings, *Agr. Eng. J.*, Vol. 9, No. 4, April, 1928.

[2] Modern Methods of Protection against Lightning, *U.S. Dept. Agr., Farmers' Bull.* 842.

Giese, Henry, Prevention of Wind and Fire Losses to Farm Buildings, *Iowa Agr. Expt. Sta. Circ.* 127.

south, and by locating all buildings in this way uniformity and improved appearance are secured. One type—or at least one color of roof covering and one color or combination of colors of paint on all buildings—lends unity and increases the attractiveness of the group. This paint combination can be carried out on fence posts and gates to give unity to the farm as a whole. A uniform design of corner and brace posts as well as of line posts helps, also, to identify the fields as belonging to this particular building group.

Protection of the building group from the winds of winter is accomplished by means of a windbreak shown on each of the farmstead plans (Figs. 3, 4, 5, and 6). This windbreak is located

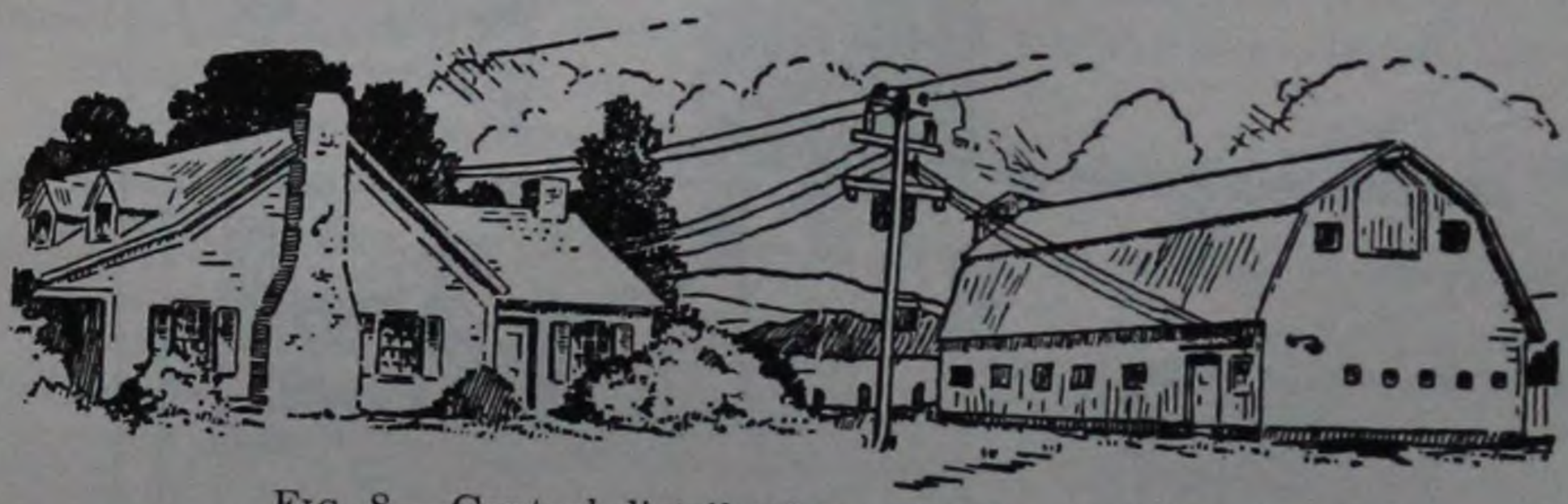


FIG. 8.—Central distributing point for electricity.

from 75 to 150 ft. from the buildings to be protected. The trees are planted in a strip not less than 20 ft. wide and containing never less than three rows of trees. These should be arranged with the tallest, most rapid-growing species on the inside and the lower growing conifers on the outside.

Water Distribution.—The delivery of water to points where it is needed on the farmstead is one piece of work that can be done automatically. If electricity is available, a pressure water system with an underground system of pipes will keep water before the livestock at all times with a minimum of attention from the farmer. Drinking troughs located in protected areas, preferably placed to take advantage of the sterilizing effect of sunshine on the troughs and equipped with a frost-proof float and valve chamber, are ideal. These troughs need not hold a great quantity of water, for it can be supplied as needed. Where electric power is not available, it may be necessary to provide an elevated tank or a cistern on an adjacent hill to provide storage and produce sufficient pressure for distributing to points needed.

Distribution of Electricity about the Farmstead.—Figure 8 shows a central pole with transformer from which leads are taken to the various buildings. In many locations this central distributing pole can be used to support the meter and an outside light for the service court.

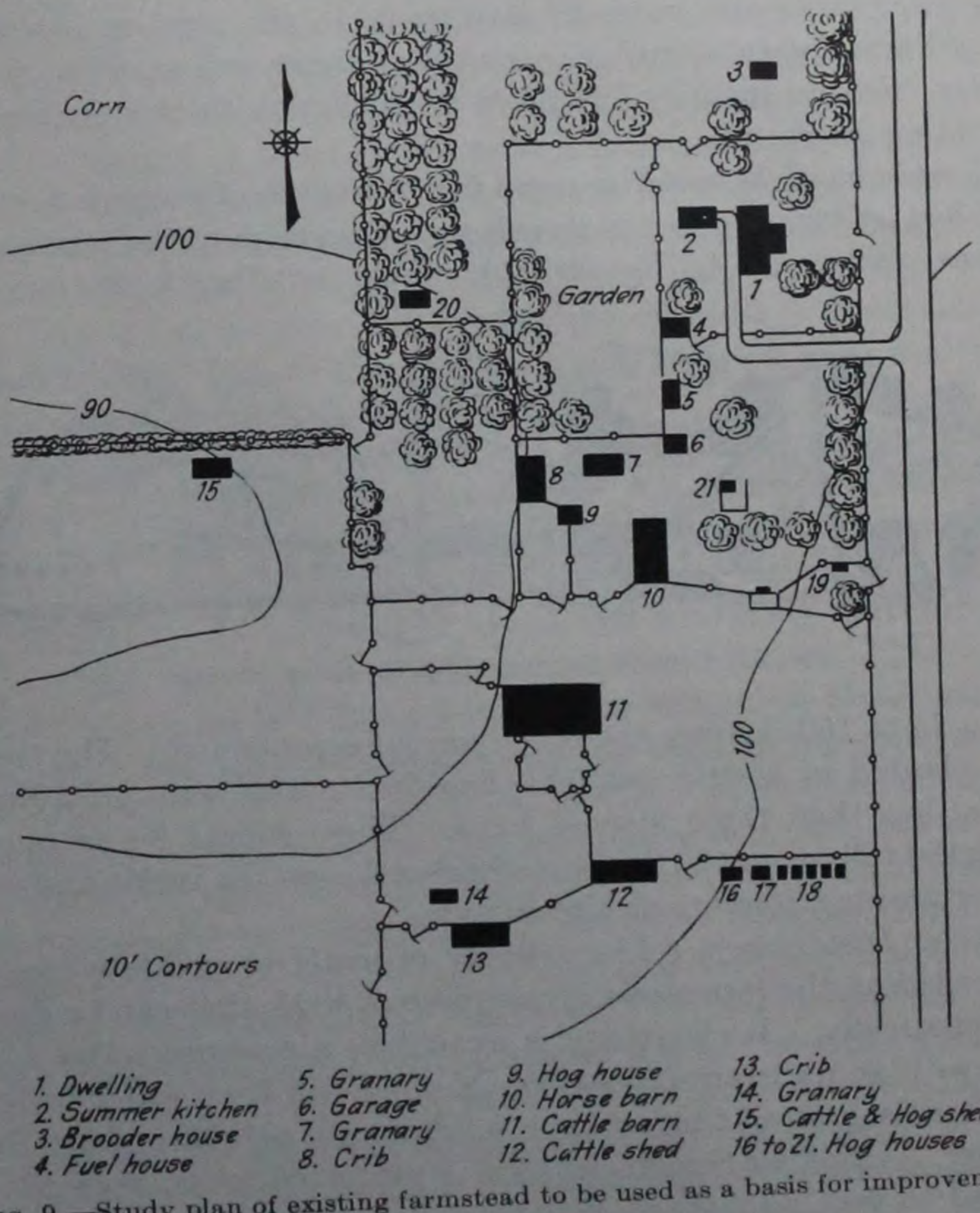


FIG. 9.—Study plan of existing farmstead to be used as a basis for improvement.

Replanning an Existing Farmstead.—Most farmsteads are permanently located, and the problem is one of replanning or improving them. In order to do this with a minimum of cost, the following procedure is suggested: (*a*) Make a plan to scale of the layout as it exists at present. (*b*) Study the plan with a view to making it more convenient, providing sanitation, improv-

ing appearance, and reducing fire risk. (*c*) Draw a plan that would give you the most nearly ideal layout possible. Frame this plan, and hang it in a prominent place. (*d*) Begin to put this plan into practice. Each time a fence or building is replaced make it conform to the new plan. As time goes on the plan will begin to take form, and no additional expense will have been incurred. Fifteen or twenty years of this procedure will result in a well-planned working unit.

Questions and Problems

18. What are some of the features that serve to make a farm attractive to people passing by on the highway?

19. What are the advantages of the central service-court arrangement from the standpoint of (*a*) efficiency, (*b*) salability of the farm, and (*c*) satisfaction and convenience in doing chores?

20. What influence has modern transportation had on the location of the farmstead on the farm?

21. Does the long, narrow field increase efficiency in the use of machinery today?

22. Criticize the farmstead layout shown in Fig. 9 for efficiency, sanitation, fire protection, appearance, and outlook from the dwelling.

Reference

WOOLEY, J. C., and M. W. CLARK: "Planning the Farm for Water Management," *Mo. Ext. Circ.*, 433.

CHAPTER VII

FENCES AND GATES

19. The General Need for Fences.—The management of runoff water, the rotation of crops, contour farming, and the increased interest in livestock enterprises, as pointed out in Chap. VI, have made necessary the replanning of a large number of farms. In many cases rectangular fields have given place to irregular-shaped fields designed to facilitate the new farming practices. These irregular-shaped fields may require more rods of fence than do the rectangular fields. This increased investment can be offset, however, by the use of temporary fences that can be moved to provide satisfactory fields for recommended crop-rotation practices. The electric fence has found a permanent place in dividing fields in the rotation as well as in other uses on the farm. Highways are no longer used as lanes for driving and grazing stock, and for this reason some farmers have omitted fences on their property lines. For the most part, however, farm boundaries are still marked with a permanent type of fence.

20. Economics of Fencing.—Many farmers have considered their fences merely one of the necessary evils on the farm and have put as little into them as possible to keep their livestock confined. Others take the attitude that fences are almost as necessary as the soil itself in carrying out their program of management. Good fences (10 rods per acre) will cost from $6 to $8 per acre if made to confine all kinds of livestock. Assuming a serviceable life of 30 years, allowing an interest rate of 4 per cent on the average value, and assuming an annual repair cost of 6 per cent, the total annual cost for good fences will be 91 cts. per acre. In order to make this investment a paying one, the fence must be instrumental in increasing the income per acre by more than the annual cost. There are a number of ways in which a fence contributes to the annual income of the farmer.

It enables him to plan his crop rotation so as to include a year of pasture for each of his fields. This pasturing off of the crop

is an important factor in building up the productive ability of the farm. During years when a field is not in regular pasture, the fence enables the farmer to turn in some of his livestock to clean up corn stalks, to utilize the grass on turn rows and around ditches, etc. Some farmers follow the practice of turning sheep into their corn fields in the early fall to clean up grass and low leaves in the field. This utilization of waste and the distribution of manure on the fields bring benefits that must be credited in large part to the fence that made such a practice possible.

A well-kept fence will protect growing crops from livestock; it will at the same time protect the livestock by preventing their getting too much green feed and perhaps becoming foundered. It will also tend to prevent livestock injury that would be more likely to occur with run-down fences that permitted stock to crowd through or over. Good fences enable the farmer to plan his work with a reasonable assurance that it can be carried on as scheduled. A well-fenced farm adds much in satisfaction each year. It decreases the difficulty many farmers have in hiring help. Most hired men do not like to work where fences and gates are in poor condition. It increases the farmer's credit at the bank and his standing among his neighbors. All these benefits added together will usually be many times more than the 91 cts. per acre annual cost for the fencing.

21. Kinds of Fence.—*Rail* fences were at one time the prevailing type, because materials for them were available, labor plentiful, the comparatively great amount of land occupied of no importance, and farms small. Today the use of the rail fence is very limited; it exists for its artistic effect rather than for its utilitarian value.

When lumber was plentiful, *board* fences were used extensively. The cost of this type of fence, however, has risen to a point where it is almost prohibitive in many sections. Board fences still have a place in the building of pens and small yards where stock is confined. They present a pleasing appearance, and the livestock confined are perhaps less liable to injury than with other types of fence.

Woven-wire fence, either stiff or hinge joint, in various heights, weights, and designs, is available at practically every trading center. The quality of such a fence is dependent on a number of factors: the tensile strength of the line wires, the gauge of the

TABLE 14.—TYPES OF FENCES RECOMMENDED*

Enclosure	Woven wire						Number of barbed wires	Spacing of posts, feet	First cost per rod*	Estimated life, years	Estimated annual cost per rod
	Number of wires	Gauge			Mesh, inches	Height, inches					
		Top	Bottom	Fillers or stays							
Fields in rotation	8	9	9	11	12	32	3	12½	$0.479	30	$0.0159
or							1 electric	25			
Hog pastures	9	9	9	12½	6	39	4	10	0.722	30	0.0241
or							2 electric	20			
Cattle or horse pastures							5	12½	0.14	30	0.0046
or							1 electric	25			
Barnyards or lanes	10	9	9	11	6	47	3	8	0.774	20	0.0387
Pasture or service lanes	9	9	9	12½	6	39	4	10	0.722	20	0.0361
Poultry yards		11	11	13	6	58		10	0.608	15	0.04

* Cost includes fence only. Posts must be computed separately.

cross or stay wires, the quality and quantity of zinc covering used, the spacing of stays, the holding power of the knot fastening stays to line wires, the efficiency of the staples or other mechanism for holding wires in place, the stiffness and durability of line posts, and the firmness and permanence of end and corner posts.

The selection of a fence for any enclosure depends on the kind and number of livestock to be pastured, the feeding program followed, and the size of the fields. Table 14 recommends types and specifications of fences for different parts of the farm.

22. Fence Posts.—The selection of posts for farm fences will be influenced by a number of factors: the availability and cost

TABLE 15.—DURABILITY AND COST OF FENCE POSTS

Variety and treatment	First cost*	Number of years service	Annual cost†
Osage orange, no treatment	$0.30	40‡	0.01
Catalpa, no treatment	0.22	35‡	0.0091
Black locust, no treatment	0.20	27	0.0112
Honey locust, no treatment	0.12	5.3	0.0226
Honey locust, painted with carbolinium	0.16	14.6	0.0179
White oak, no treatment	0.15	13.5	0.0192
White oak, painted with carbolinium	0.19	20.6	0.0140
Concrete	0.44	40‡	0.0140
Steel	0.35	40‡	0.0090

* First cost of posts will vary in different localities. The figures in this table were based on local Columbia, Mo., prices.

† The annual cost equals the first cost plus the cost of setting or treatment divided by number of years of service.

‡ Estimated.

of different kinds of posts in the community; the length of service desired in the fence; the kind of fencing material to be used; the kind and amount of livestock to be confined; the serviceability of different varieties of fence posts; and the cost of installation. In the management of a farm there may be times when available cash is low and labor is plentiful. Such circumstances often lead the farmer to select the fence that can be installed with the lowest cash outlay, even though the labor requirement is high. Good management, however, usually demands the lowest annual cost, quality of service being considered.

Corner and End Posts.—"A fence is no better than its end and corner posts" is a common statement that has in it much truth.

A slight movement of an end post may allow the fence to move out of line a considerable distance at the center of the span. Of course, posts support the fence at frequent intervals, but any slack in the fence line allows livestock to push through, damaging the fence and causing rapid depreciation. Thorough bracing of end posts is essential. The type of bracing shown in Fig. 9 is satisfactory when posts and poles are plentiful.

This type of bracing has a number of faults that have caused its use to be decreased materially. It exerts a lifting action on the corner post that limits its effectiveness; rain water drains

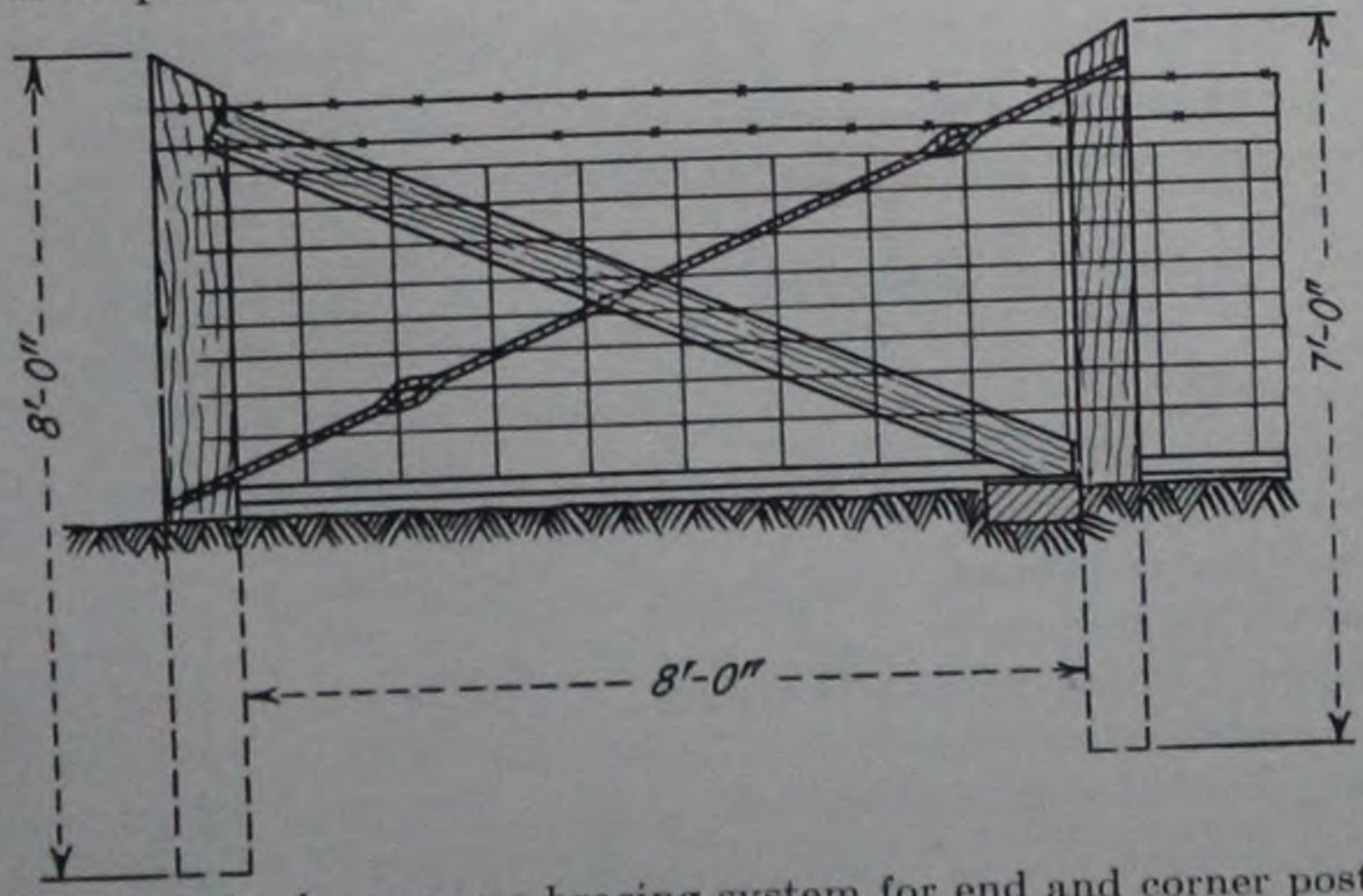


FIG. 10.—Angle- or cross-bracing system for end and corner posts.

down along the brace, causing early decay; and the serviceable life of this type of bracing is still further limited by the brace being near the ground on one end. Some excellent work has been done on the efficiency of different end and corner braces at Iowa State College under the direction of Prof. Henry Giese.[1] In these tests it was found that braces as shown in Figs. 11 and 12 were quite satisfactory. The single brace (Fig. 11) is recommended for short spans and the double brace (Fig. 12) for longer spans or points where heavier strains are expected. Short fences will exert a pull of as much as 2,000 lb., and longer lines may require double the resistance to keep the fence in shape.

The horizontal brace shows slightly less tendency to lift the corner post than does the angle brace. The horizontal member is away from the ground and for this reason it should give longer

[1] GIESE, HENRY, and MAXTON D. STRONG, The Construction of Fence Ends and Corners, *Agr. Eng. J.*, Vol. 21, No. 4, April, 1940.

service. Using the same span between end and brace post, Giese and Strong found that the horizontal brace held from 20 to 35 per cent more strain than the angular or cross brace. They found, also, that the double brace (Fig. 12) held more than twice the load that could be applied to the single brace (Fig. 11),

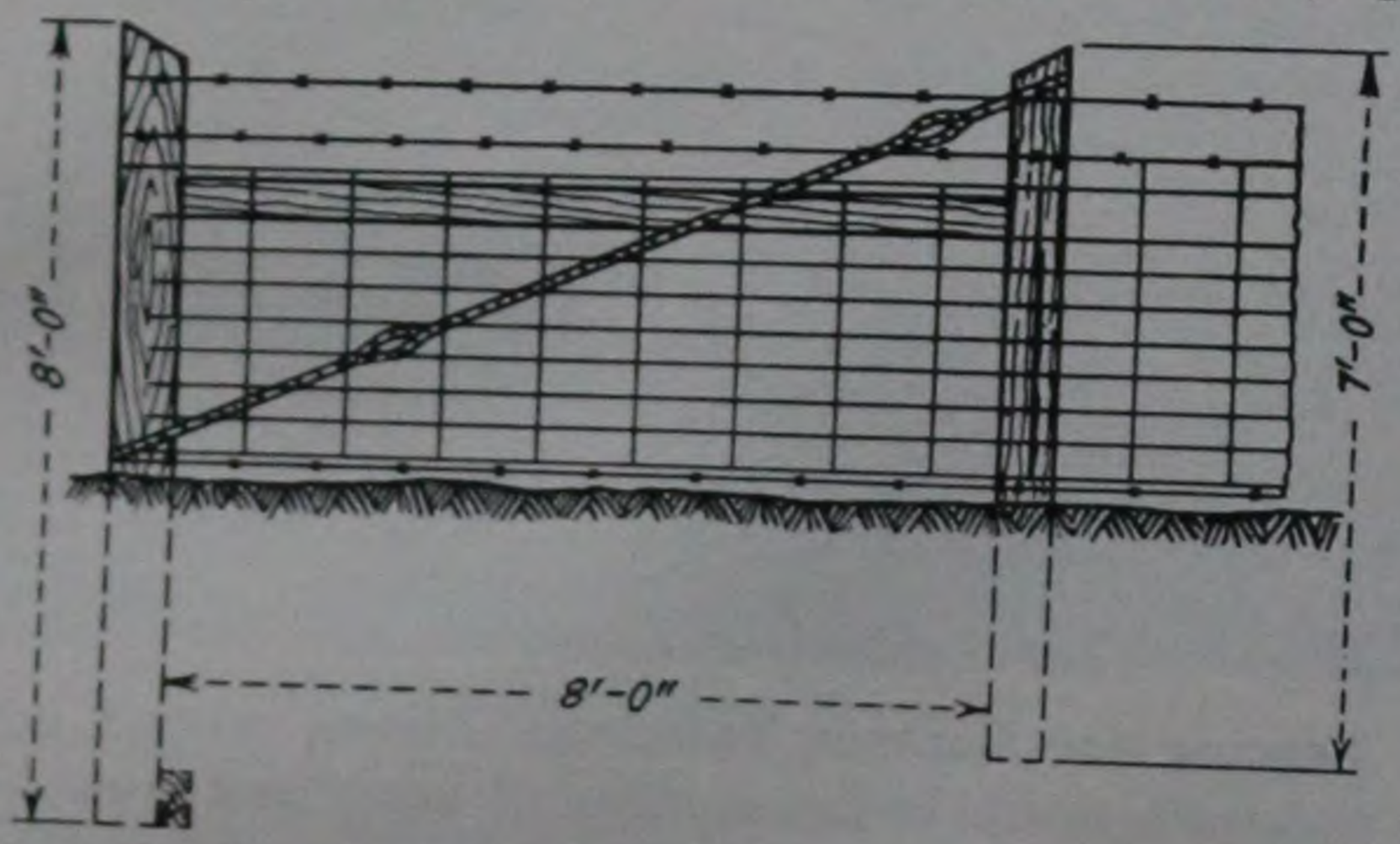


FIG. 11.—Single horizontal brace for ends and corners.

and this with half the vertical and less than half the horizontal movement.

Anchors fastened to the post as shown increased the effectiveness of the brace. These anchors should be made of treated lumber 14 in. or more in length.

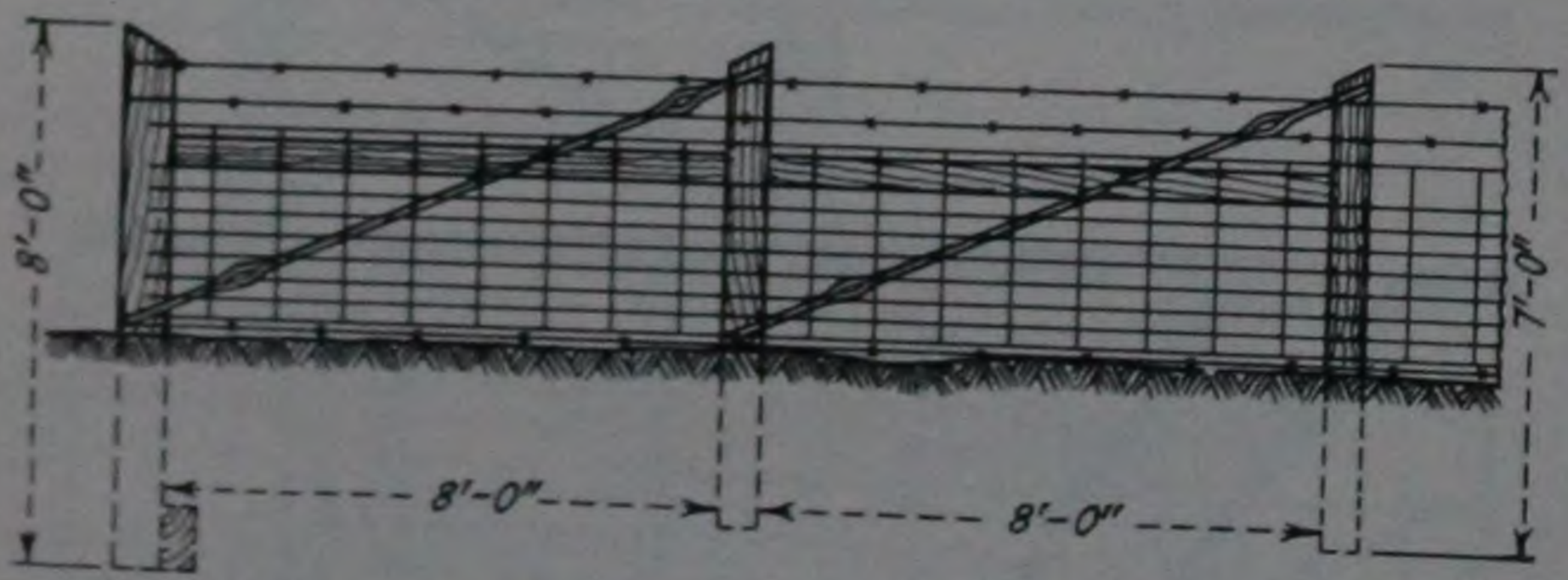


FIG. 12.—Double horizontal brace for ends and corners.

The steel-post and brace assembly shown in Fig. 13, when set in concrete, has been found to be satisfactory in practical use, although no tests have been reported on it. A special anchor is used by telephone and telegraph companies and is being manufactured in sizes suitable for farm fences. An installation of

this type is shown in Fig. 14. This assembly can be installed as shown, or it can be placed in the line at any point where excessive tension occurs.

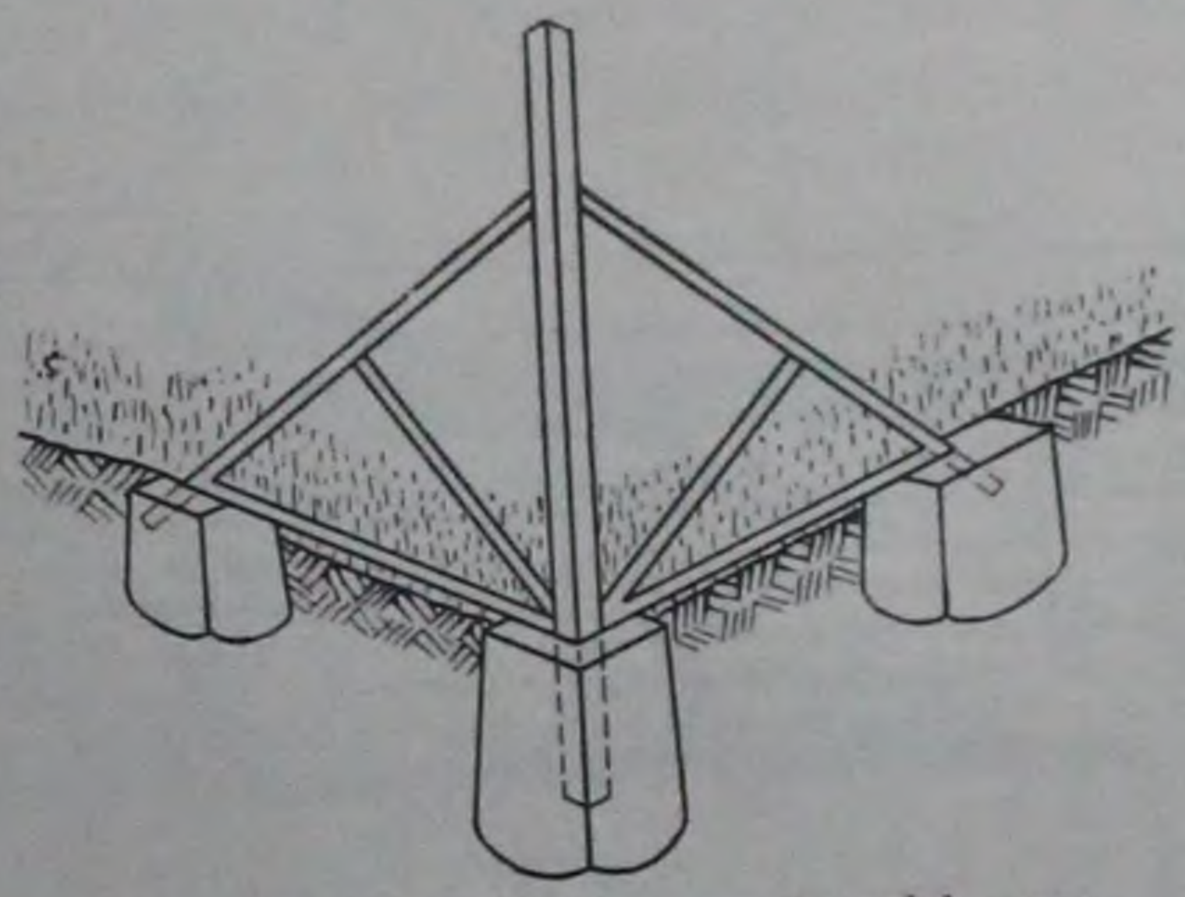


FIG. 13.—Steel corner post and braces.

23. Fencing for Contour Farming.—Fences around contour fields require a much larger number of brace and corner posts than fences around rectangular fields. Fences, unless they are of the electric type, cannot be built on curved lines. It is necessary to build them in straight sections in order to maintain the tension necessary for rigidity and strength. A post located at

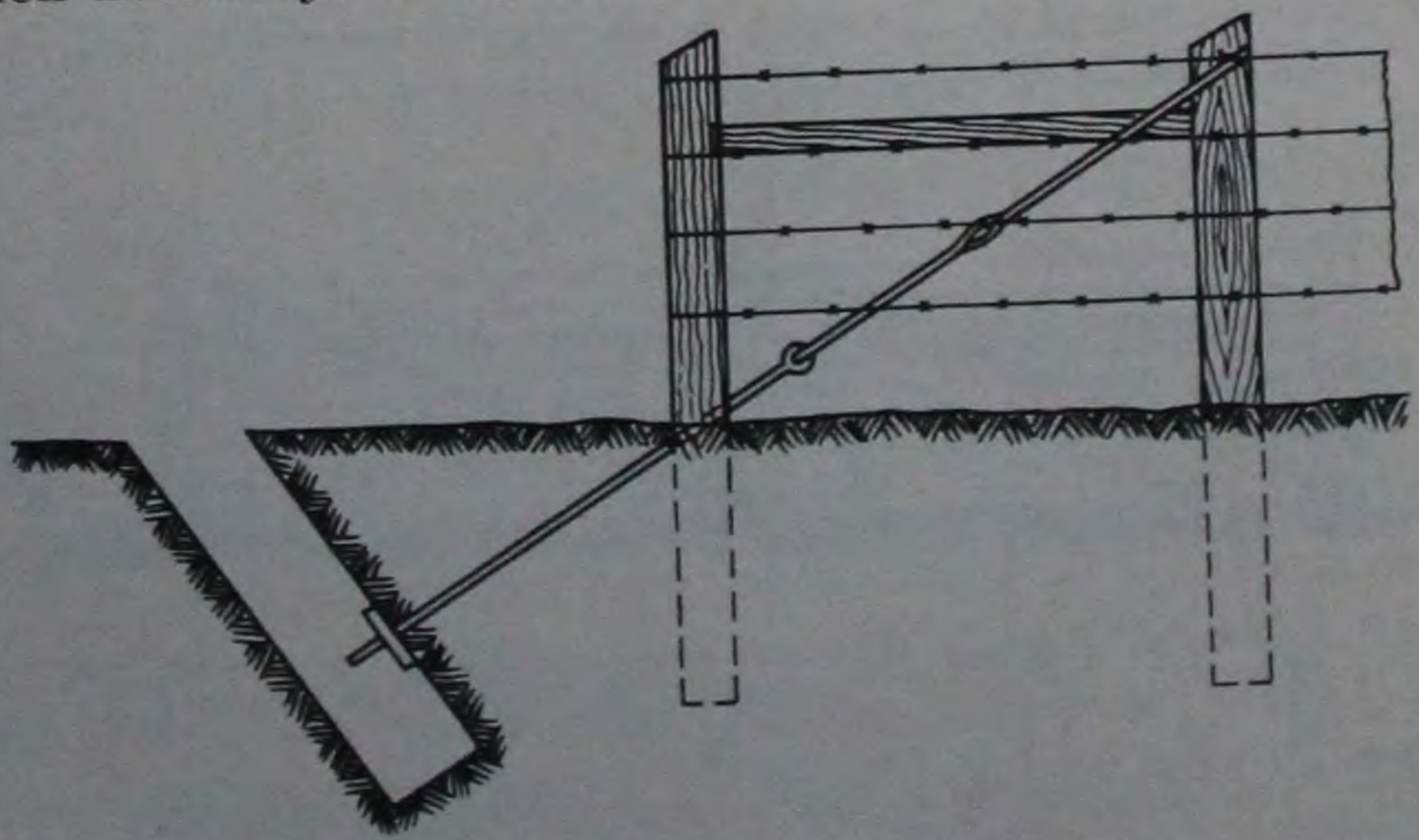
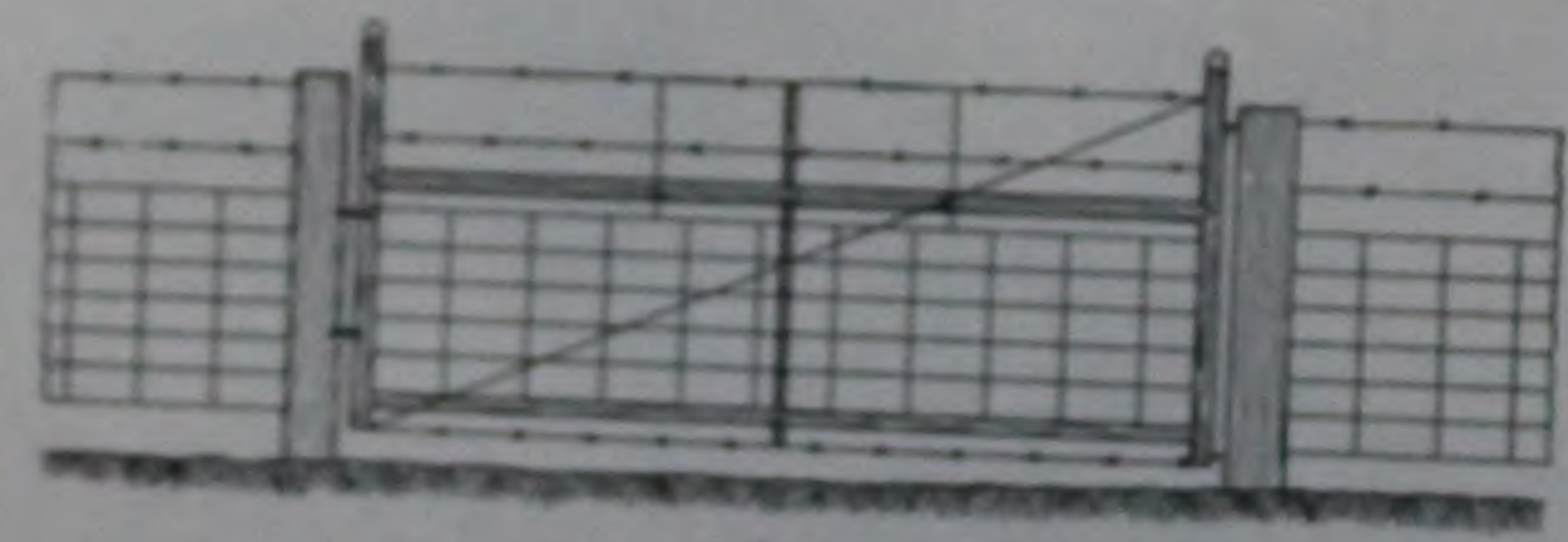


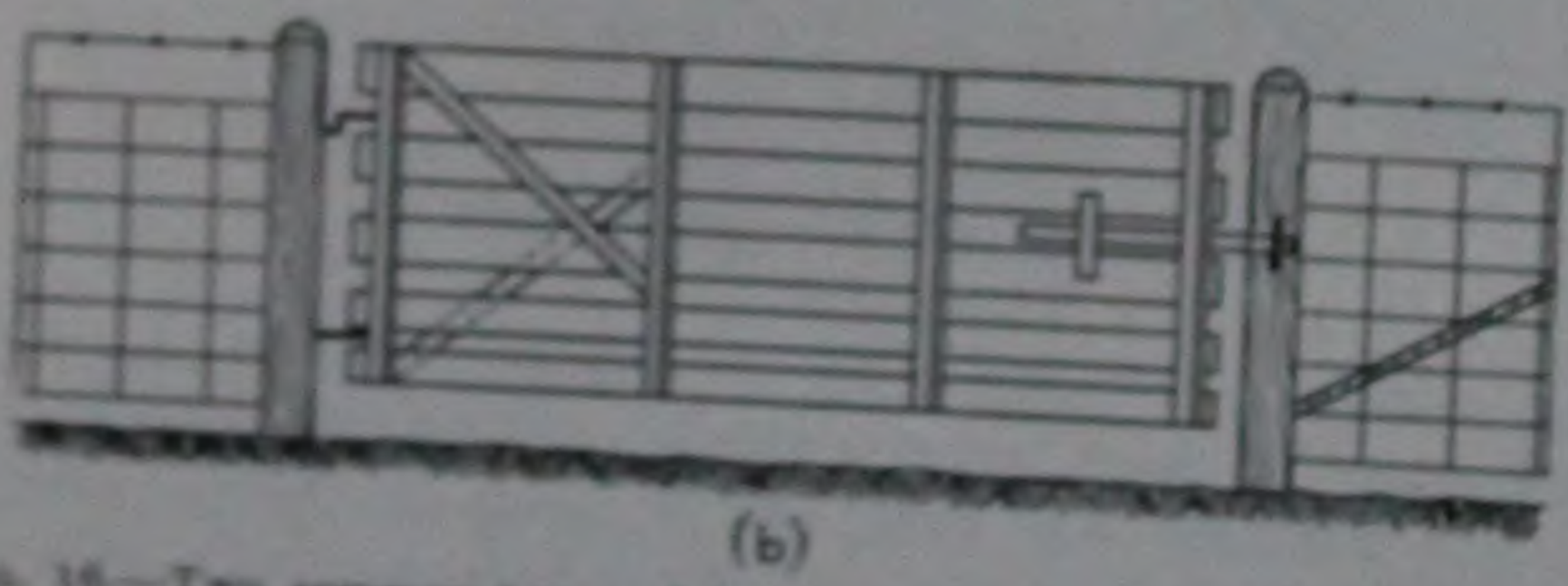
FIG. 14.—Anchor for end or corner post.

the point where a change in direction is made may be braced so that it will remain in a vertical position but not necessarily resist tension in any one fence line. The two lines will hold against each other, and so long as the post is held in an upright position

FIG. 15.—Contour fences.



(a)



(b)

FIG. 16.—Two common types of farm gates: (a) steel gate; (b) wood gate with steel cross bars. This gate has one advantage in that boards can be replaced easily if they are damaged.

the tension in the fence line will be maintained. A single brace may be placed so as to bisect the angle between the two fence lines, or two braces for these corner posts may be placed directly in the fence line, as would be done for any other type of fence. The anchor shown in Fig. 14 is used also to meet this condition.

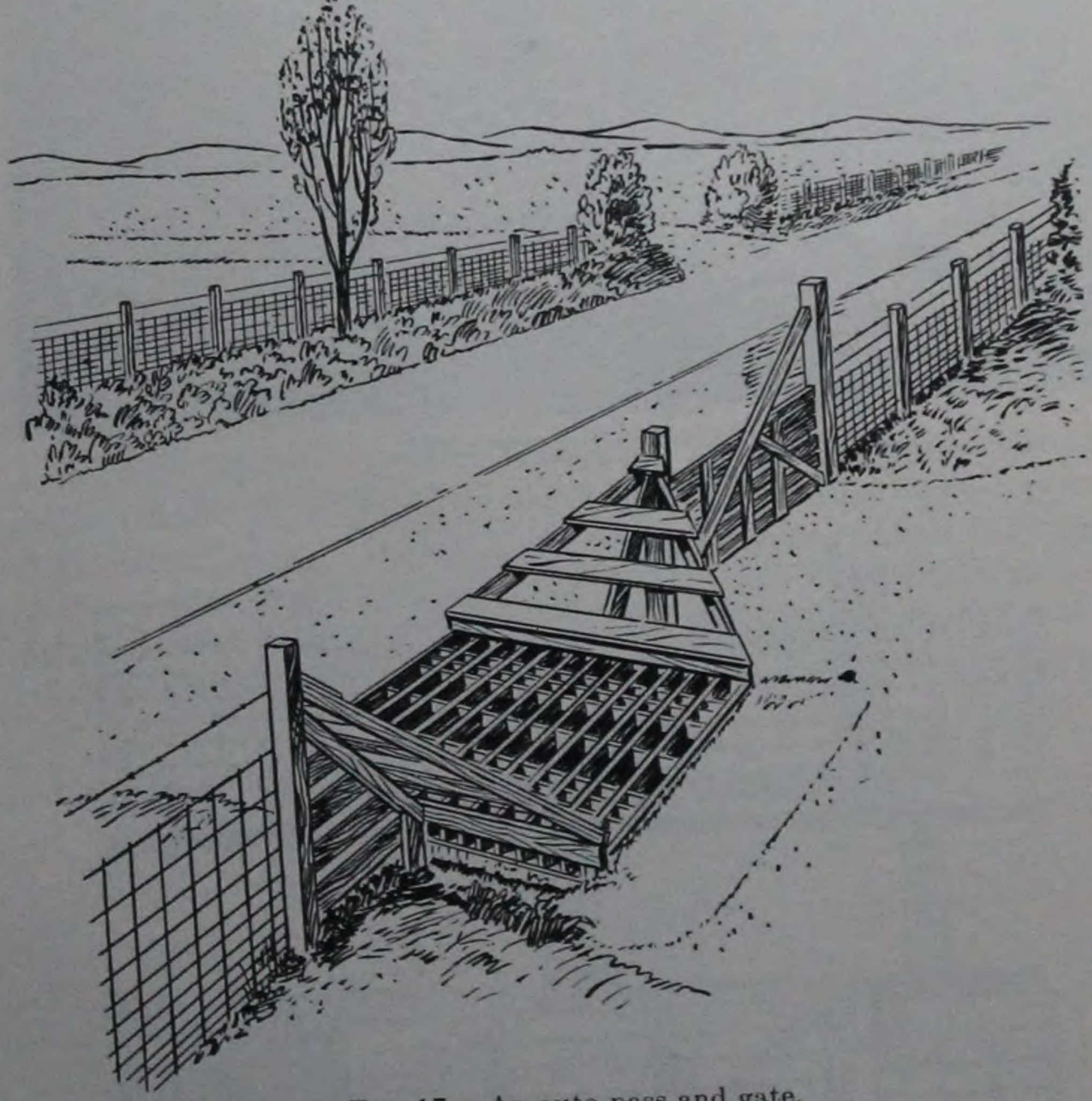


FIG. 17.—An auto pass and gate.

The so-called "contour fence," which follows the approximate contour, is made up of a number of straight sections (see Fig. 15). Sections less than 150 ft. long are to be avoided because of the excessive amount of bracing required. If a terraced field is divided, the fence is built as nearly parallel to the terrace above it as is practical. There will then be no point rows between the fence and the terrace.

24. Gates are probably subjected to more wear than any other part of the fence. Livestock become accustomed to passing through gates and consequently give them harder service than any other point on the fence line. Gates must not only perform the functions of a fence but must be made to move out of the way in a convenient manner. Self-opening gates, for the most part, are expensive and often do not stand up well under heavy use. For this reason their use is somewhat limited. The simple swinging gate made of steel or of wood is most popular. Figure 16 shows two common types of farm gates.

The so-called "auto pass" to be used for cars and trucks with an ordinary gate beside it for teams makes a satisfactory combination. If properly designed and constructed, the auto pass makes an effective barrier for livestock and saves much time and trouble when the car is used (see Fig. 17).

Questions and Problems

23. Can a farmer build any kind of fence he desires on the division between his farm and his neighbor's land?

24. If farmers generally adopt a program of soil improvement, will this increase or decrease the amount of fence required? Explain.

25. Willow timber is cheap, and posts are easily made from it. Would a farmer ever be justified in building a fence using willow posts? Explain.

26. A farmer has just purchased a 160-acre level farm that he expects to lay out according to the plan shown in Fig. 2 in Chap. VI. Draw a plan of this farm to a scale of 24 rods = 1 in. Designate each fence line by a letter. Make up a table showing the fence line, length, number of line posts, number of brace posts, kind of fence, and number of gates. Make a list of the materials needed to fence the farm. Figure the cost of all this material and the annual cost of the fencing on this farm.

PART II

Livestock and Poultry Buildings

CHAPTER VIII

PLANNING BUILDINGS FOR THE DAIRY ENTERPRISE

25. Special Planning Required.—The dairy barn is one of the buildings on the farm in which food for human consumption is handled and processed. Many foods might be handled safely in a questionable environment, because they are somewhat protected from contamination by their form or covering; also, most of these foods are to be exposed to intense heat in the process of cooking, which tends to make them safe so far as harmful bacteria are concerned. Milk is one of the more easily contaminated foods. It furnishes an excellent medium for bacterial development, and when first drawn from the cow its temperature is favorable to rapid bacterial growth. Much of the product is used in the raw state, providing no means for the destruction of harmful bacteria that may find their way into it. Milk retailed through regular dairies is pasteurized to make it safe, but this does not justify any laxity in care to keep it as pure as possible.

Barn dust is a very potent source of contamination. Condensation from the breath of cows settles on the dust particles, and, being deprived of the sterilizing action of the sun's rays, it becomes heavily laden with bacteria. An extremely small particle of this dust is sufficient to contaminate a rather large quantity of milk.

Flies are also a potent source of contamination. Alfred Hopkins, an eminent English authority on sanitation, expresses the opinion that if a fly were submerged for a few minutes in a cubic centimeter of milk and the fluid were then examined under a microscope it would not be unusual to have the slide show from 100,000 to 1 million bacteria. In addition to causing discomfort to the animals, loss in production, and inconvenience to the

operator, flies constitute a real menace through contamination of the milk supply.

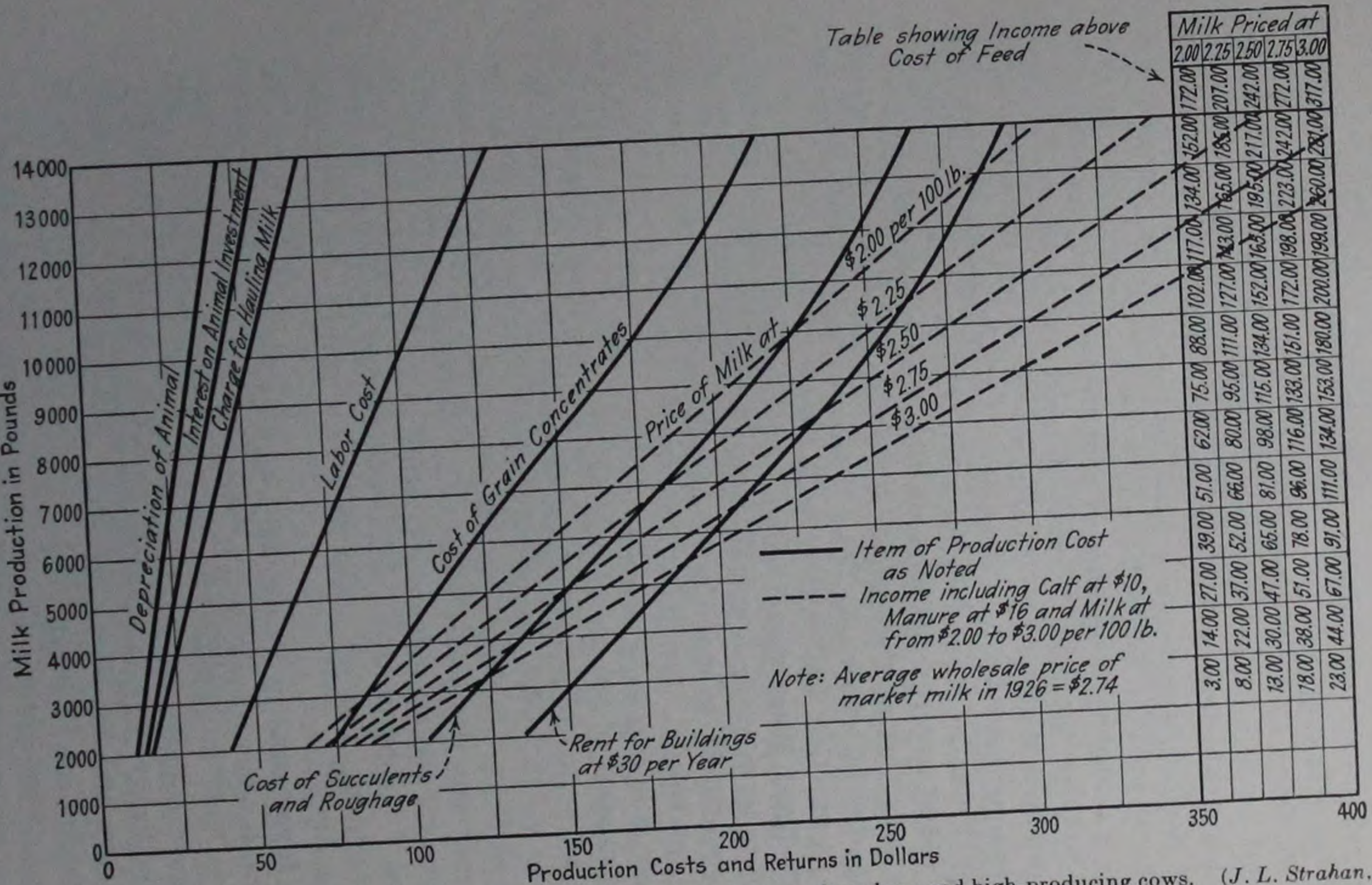
26. Dairy Cows Are Efficient Animals. Any animal that is called on to work at a high rate of efficiency must be provided with a satisfactory environment if good results are to be expected. The dairy cow performs a large amount of work changing raw material into the finished product, milk. These processes produce a considerable amount of heat that must be removed from the body of the cow. Carbon dioxide and moisture are other by-products that must be taken care of to ensure the comfortable environment needed for efficiency. It is natural to assume that an environment is comfortable when it meets human standards, but recent experiments indicate that the comfortable temperature for a high-producing cow is considerably lower than would ordinarily be expected. The optimum barn temperature for milk production lies between 50 and 80°F.[1]

27. Good Plans Save Labor.—Operating a dairy enterprise consists in carrying out many repeated processes, thus offering an opportunity to make a considerable saving in labor through good planning. Manufacturers spend considerable time and money studying each move in an operation that is repeated a great number of times. If they can shorten each movement by only a fraction of a second, the accumulated total for the day may be worth while. A careful study of the different operations to be performed in a dairy barn may not only shorten the time for the work but also make it less tiring or perhaps more pleasant. This may have an influence in attracting hired help if such is needed. A laborer, other things being equal, will elect to work for the man who can offer good equipment and attractive surroundings.

28. Investment in Equipment.—One thing that must always be considered in setting up an enterprise is the optimum investment in fixed equipment. If the investment is too high it will constitute a drain on the business that may prevent profits' being realized. The dairy enterprise is no exception to this rule. If cows are high producers and prices are good the investment in fixed capital can be large.

Figure 18 shows the influence of production rate on the justification of different items in the cost of production. For example,

[1] KELLY, M. A. R., *Agr. Eng. J.*, Vol. 9, No. 6, p. 186, June, 1928.



Milk Production in Pounds	Milk Priced at 2.00	2.25	2.50	2.75	3.00
14000	172.00	207.00	242.00	272.00	317.00
13000	152.00	185.00	217.00	242.00	281.00
12000	134.00	165.00	195.00	223.00	260.00
11000	117.00	143.00	165.00	198.00	199.00
10000	102.00	127.00	152.00	172.00	200.00
9000	88.00	111.00	134.00	151.00	180.00
8000	75.00	95.00	115.00	133.00	153.00
7000	62.00	80.00	98.00	116.00	134.00
6000	51.00	66.00	81.00	96.00	111.00
5000	39.00	52.00	65.00	78.00	91.00
4000	27.00	37.00	47.00	51.00	67.00
3000	14.00	22.00	30.00	38.00	44.00
2000	3.00	8.00	13.00	18.00	23.00
1000					
0					

Production Costs and Returns in Dollars: 0, 50, 100, 150, 200, 250, 300, 350, 400

FIG. 18.—Relation between milk production costs and income per cow, per year, from low- and high-producing cows. (*J. L. Strahan, Agr. Eng. J., Vol. 9, No. 1, January, 1928.*)

cows producing less than 6,500 lb. of milk yearly will not bring returns beyond the cost of feed, and a smaller rate of production may not even pay for feed consumed. Any investment in a barn for this kind of cow would hardly be justified. However, a cow producing 12,000 lb. per year may justify an expenditure of $250 for buildings without decreasing the returns from the enterprise.

Consumers must be considered in planning. Milk ordinances are rules laid down by representatives of the consuming public for the production and handling of milk for public use. They rightfully have something to say about how the barn is arranged, the materials from which it is made, and how it is cared for. They demand a clean bill of health for the workers and even specify the kind of clothing the workers wear. The consumer pays more for his product, but apparently he is willing to do so because he knows it is wholesome.

29. Factors and Regulations Governing Barn Design.—Most milk ordinances set forth a number of regulations applying to the design and construction of barns. Impervious, washable floors, laid so as to drain well, are essential. Side walls and ceilings must be smooth and tight. Projections from the wall that will catch dust are to be avoided. Some designers set windows so that they will be flush with the inside wall surface to prevent collection of dust on sills. Some ordinances require that walls and ceiling be whitewashed once each year or painted once each 2 years. Floors must be scrubbed or covered with slaked lime once each day. Cobwebs and dust must be brushed down or the walls and ceilings washed frequently.

Most ordinances do not go so far as to require screens on the barn, but they are unanimous in requiring screens on the milkhouse. Many dairymen, recognizing the menace produced by flies, have provided screens on windows and doors of their barns, also. In some instances special equipment is provided that brushes flies off as the cows enter the barn. Most of these devices not only keep the flies out of the barn but also trap them, making it possible to reduce the hazard from this source.

Disposal of Manure from the Dairy Barn.—Manure should be removed from the barn before each milking. It may be hauled to the fields and spread each day, it may be piled in the yard at a

reasonable distance from the barn for a period of not to exceed 4 days, or it may be stored in a fly-tight impervious pen or pit. Many barns are not equipped with drive-through service alleys, and it is necessary to move manure to one of the stable doors for loading on the spreader. Two methods of handling the manure

TABLE 16.—AMOUNT AND VALUE OF MANURE*

Animal	Per year	
	Tons	Value
Horse	5.2	$31.67
Dairy cow	8.5	38.76
Other cattle	4.0	21.88
Sheep	0.4	3.86
Hog	0.6	3.71

* *Penn. Univ. Expt. Sta. Circ. 67.*

under such circumstances are now in use: one consists of an overhead track system; the other requires surface carts equipped with pneumatic tires. The method used will influence the design of the barn as well as the manure pit. The size of pit will be determined by the number of cows in the herd and the length of the storage period. Where the operator of the farm arranges to clean the pit whenever it is possible to spread manure on the fields, a 5-or-6-week storage period will usually be sufficient. Table 16 gives information on the quantity and value of manure accumulated from stables housing different kinds of animals during a period of 1 year.

In a period of 6 weeks, approximately 1 ton of manure would need to be stored for each cow. Manure weighs about 25 lb. per cubic foot, and therefore 80 cu. ft. of storage space would be needed per cow.

A pit dug into the ground is ideal so far as the storage of manure is concerned and is convenient for getting the material into it. However, the work of transferring the manure from the pit to the spreader may be very difficult. In the larger pits a drive-through arrangement is recommended. Figure 19 shows a desirable manure-storage structure for short storage periods.

Lighting.—Good lighting in the barn is essential. It may come from windows or from artificial sources. Some ordinances

call for 4 sq. ft. of glass area per cow or a smaller glass area supplemented by adequate artificial light. The 4 sq. ft. of glass per cow may result in excessive heat loss unless shutters are provided to cover the windows on cold nights. By using special window glass that will admit a part of the ultraviolet light of the sun, much of the benefit of direct sunshine can be secured. Artificial ultraviolet light has been found to bring good returns in some instances, especially with young animals.

FIG. 19.—A manure-storage structure.

When the dairy barn is wired for electric lights the location of these lights is important. Figure 27 shows a wiring plan for an 18-cow, individual-stall type of barn. In this plan the cows face in to a central feed alley. The lights are placed about 12 ft. apart and are alternated from one side of the alley to the other to leave clear space in the center for an overhead feed carrier, if one is to be used. If a feed cart is used the lights may be placed in the center of the alley as shown. This close spacing will permit the use of lower wattage lamps and may result in a better distribution of light.

To facilitate the work of milking and cleaning, the lights are spaced in a similar manner and should be placed over the gutter

as shown in Fig. 27. This furnishes good light for milking and for cleaning floors.

Individual switches on each line will result in economy in the use of current and enable the caretaker to have good light for the particular work he is doing.

Ventilation, though provided primarily for the benefit of the cows, has a place in improving the conditions for handling milk. When odors and impure air are removed the chances for contamination of milk are greatly reduced (see Chap. XVII for a more complete discussion of ventilation systems).

Many ordinances contain regulations for the handling of feed, especially of hay. Authorities are agreed that hay should not be thrown down into the milking barn unless a closed chute is provided. Usually one part of the barn is set aside for maternity and calf pens. The hay can be thrown down in this part provided it is separated from the milking part by a tight partition.

Rather definite regulations are set up for the handling of milk. Partly covered milk pails, where hand-milking is done, are recommended. The milk from each cow must be delivered to the milk room as soon as it is drawn. The milk room must not open directly into the milking barn but must have a ventilated hallway between. Where the milkhouse is adjacent to the barn, a covered connecting walk provided with good cross-ventilation is satisfactory.

After the milk is delivered to the milk room it must be cooled down to 58°F. within 20 min. and held at this or at lower temperatures until delivered. Where running water is available with a sufficiently low temperature to meet these requirements, the cooling tank shown in Fig. 20 is recommended. Usually the water pumped for livestock is allowed to flow through this tank, entering at the bottom and escaping at the top through the standpipe shown. This arrangement removes the water that is warmed by the milk, and the lowest possible temperature is maintained at all times.

If the water supply is limited or if the temperature is not sufficiently low, ice may be added to produce the desired results. An insulated tank is then desirable. Figure 21 shows such a tank built from concrete. Waterproofed insulation can be obtained in convenient sizes and can be placed readily as the concrete is poured.

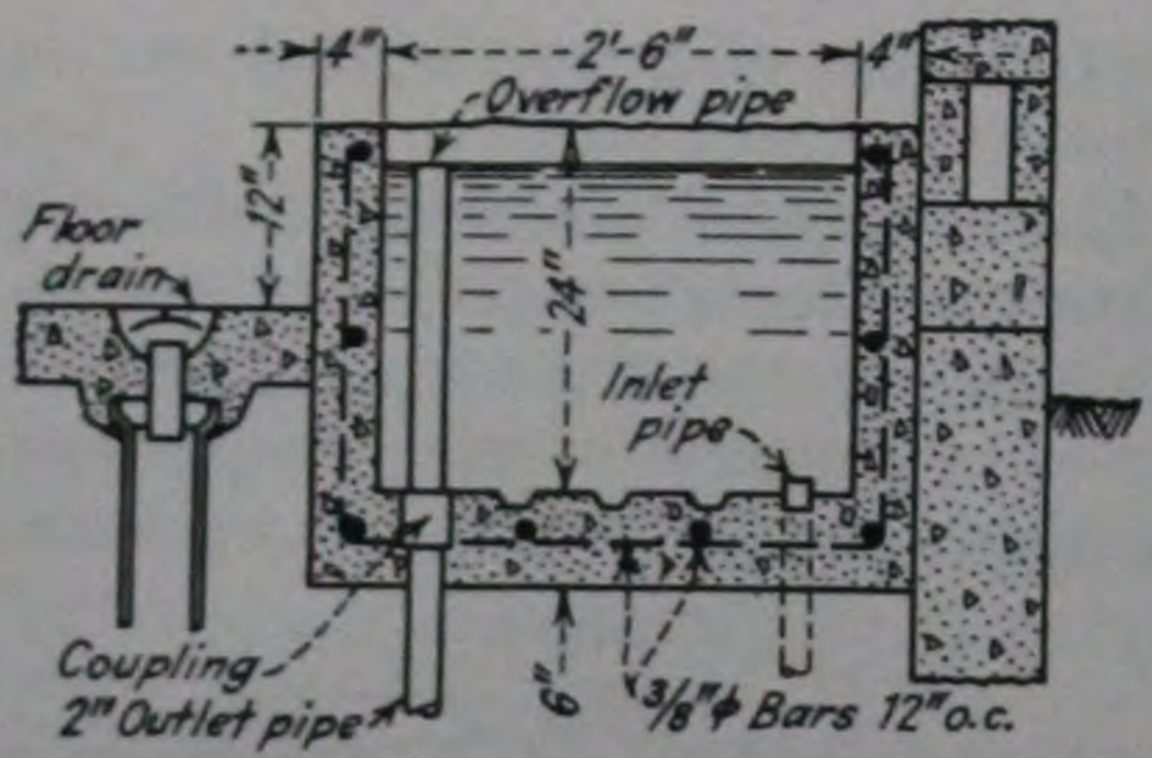


FIG. 20.—Uninsulated tank recommended for conditions where a plentiful supply of cold water is available.

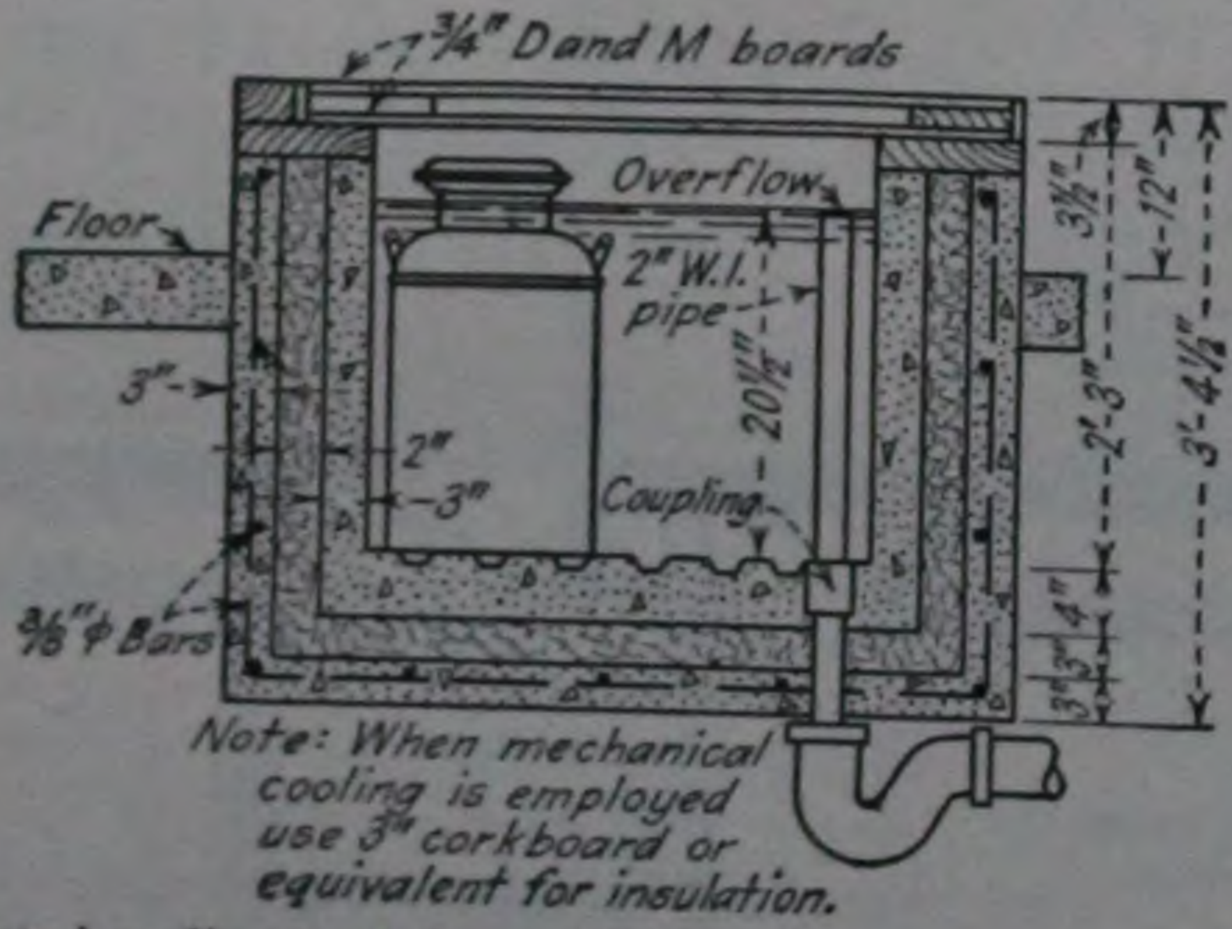


FIG. 21.—Insulated cooling tank for conditions where water temperature must be lowered by the addition of ice.

30. The Milkhouse.—State and city ordinances are very strict in regard to the care of utensils in which milk is transferred and processed. They all agree that the kitchen is not the proper place for washing these utensils. It is sometimes difficult for inspectors to impress on dairymen that kitchens may be a source of contamination for the milk supply. Most people are quick to realize, however, that the utensils used for the milk and in the process of milking offer fertile ground for the development of disease germs of various kinds that may find their way into the kitchen through the various cleaning processes concentrated there. Utensils cared for in the milkhouse are not exposed to

contamination from any other source, and usually the kitchen is better off without this extra burden.

There should be provided a separate milkhouse or milk room for the handling and storage of milk and the washing and disinfecting of milk apparatus and utensils, provided with a tight floor constructed of concrete or other impervious material and graded to provide proper drainage. The walls and ceilings of the

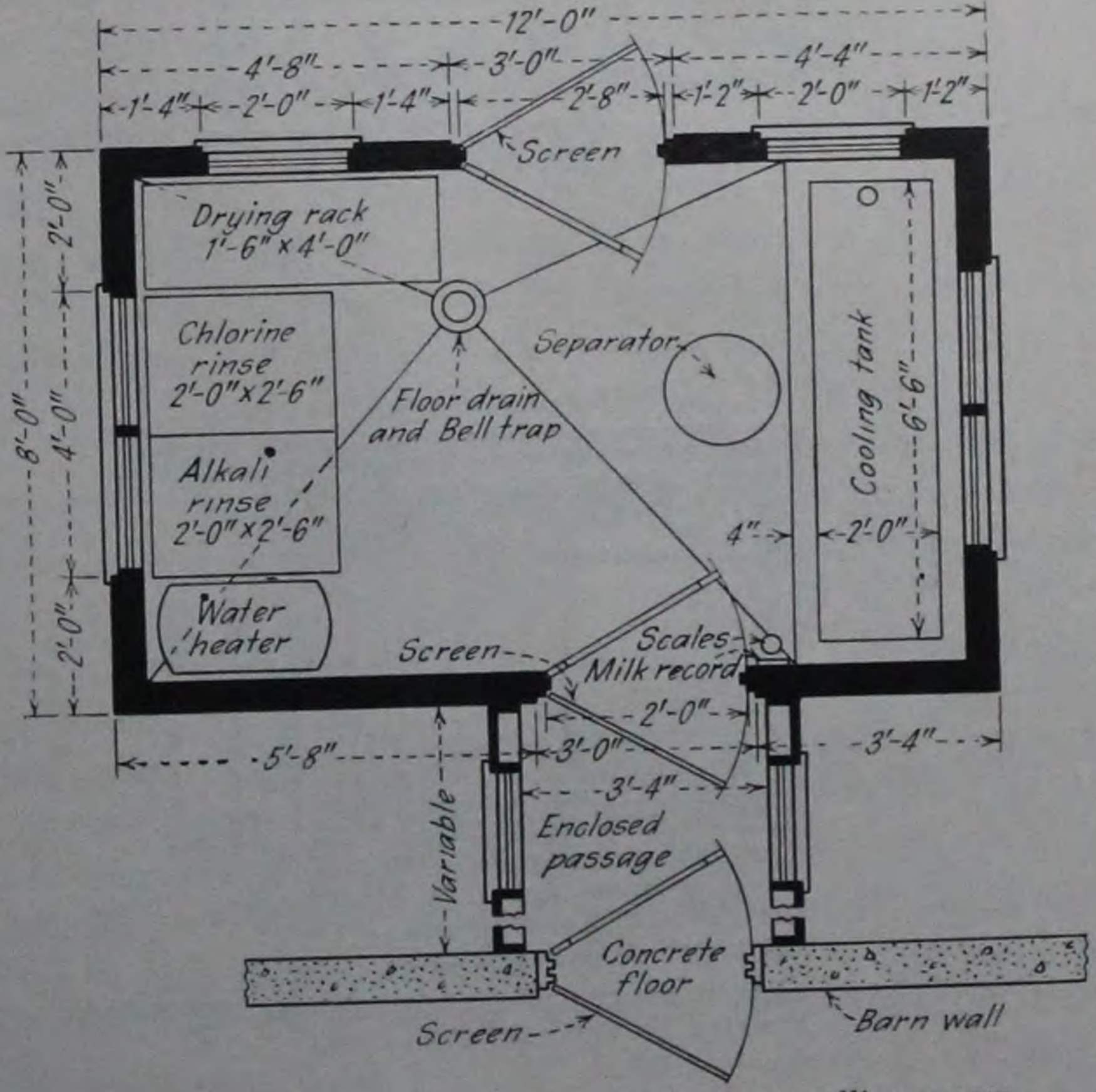


FIG. 22.—One-room milkhouse for the farm selling cream.

milkhouse or milk room should be of such construction as to permit easy cleaning and should be painted at least once a year or finished in a manner approved by the health officer.

The milkhouse or milk room should be well lighted and ventilated, with all openings effectively screened to prevent the entrance of flies, and should be used for no other purpose than the handling and storage of milk or milk products and other operations incident thereto. The cleaning and other operations should be so located and conducted as to prevent any contamination of the milk or of disinfected equipment. The milk room

should not open directly into a stable or into any room used for domestic purposes.

The size of the house and the number of rooms will be governed by the size of the enterprise and the method of marketing the product. Figures 22, 23, and 24 show different types of houses to meet varying needs.

The milkhouse must be located so that livestock will not have access to yards immediately surrounding it. The central service

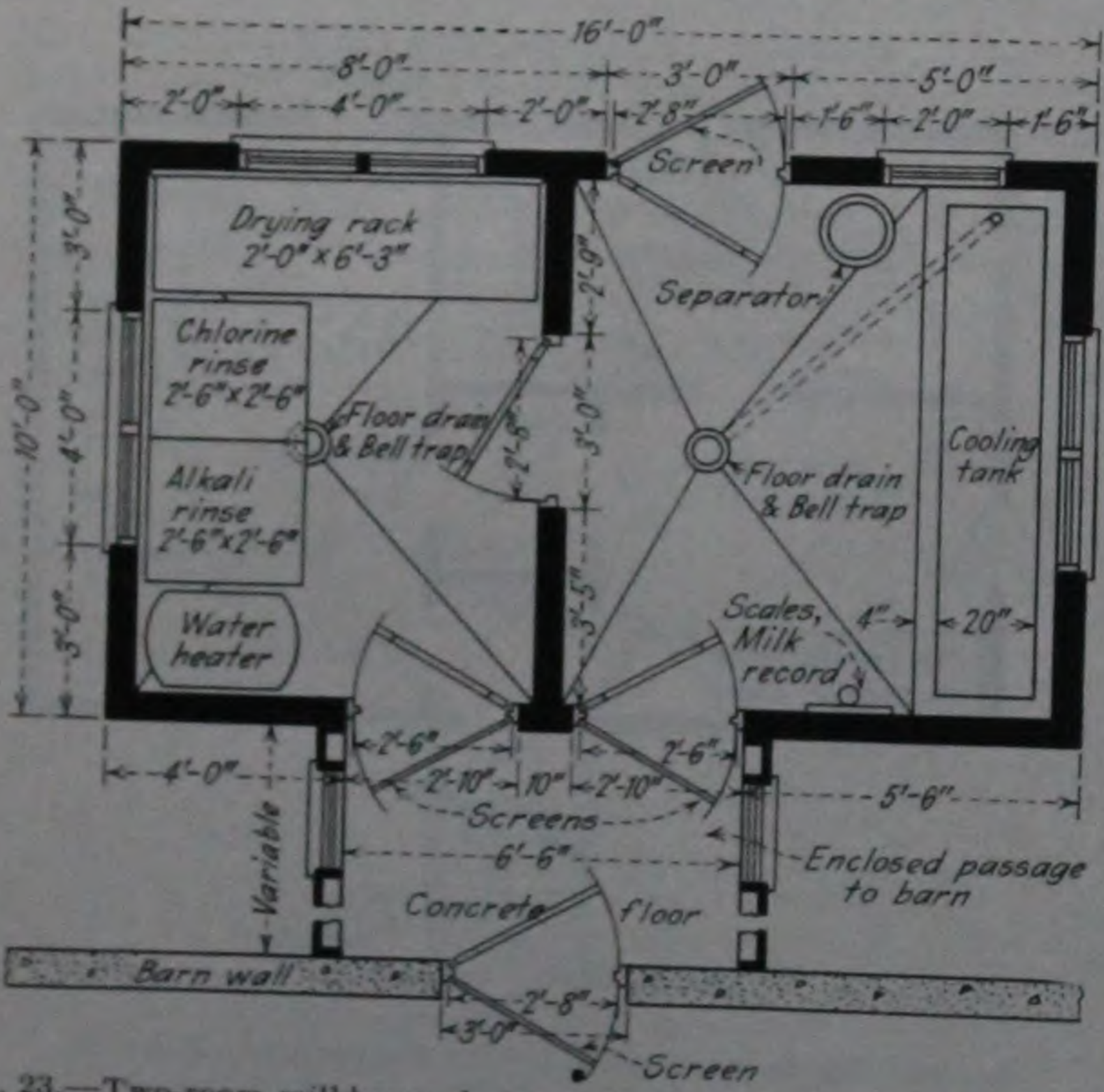


Fig. 23.—Two-room milkhouse designed for the farm selling milk in bulk.

court of the farmstead is the proper location for the milkhouse, since it will be necessary to load products out of it for market.

31. Environment for Health and Efficiency of Dairy Stock.—Selection of dairy cows has been made largely on the basis of production. Most of the dairy breeds were developed in localities having mild, even climates. The transfer of these animals to the rigorous climate of some of our dairy states provides a very great change of environment. The dairy barn must then prevent extremes in temperature, keep present a continuous

supply of fresh, dry air, and provide easy access to a plentiful supply of feed and water at all times. Well-bedded stalls or pens with equipment that makes for ease in handling the cows result in a decrease in nervousness of the animals and an increase in their general well-being.

The use of drinking cups in individual stalls or in loafing pens results in increased production and in maintenance of health of animals. Cows drink frequently during the feeding period and

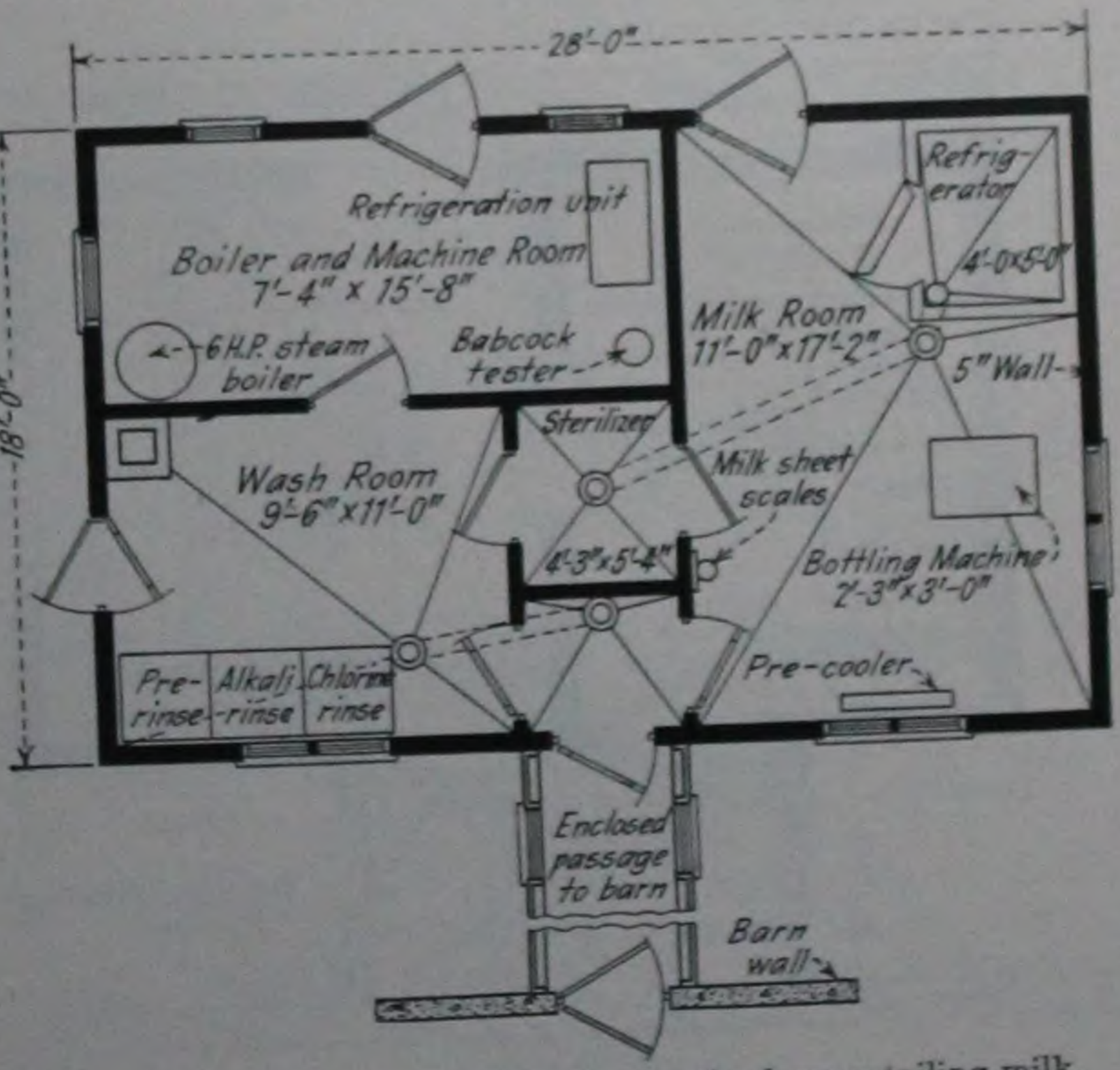


FIG. 24.—Three-room milkhouse for the farm retailing milk.

consume a greater amount of water during the day when it is provided in this convenient manner for them. An experiment at Iowa State College on the use of drinking bowls showed that dairy cows watered by means of water bowls drank approximately 18 per cent more water and yielded 3.5 per cent more milk and 10.7 per cent more butterfat than cows that were watered twice a day in an outside tank. Cows watered with bowls drank 10 times each 24 hr. The temperature of the water did not influence water consumption so much as did the temperature of the atmosphere.

Questions and Problems

27. The milking barn should be as clean as a kitchen. Is this statement true? Would it apply more appropriately to the milkhouse? Should the milk ordinance provisions in regard to the milker's clothing, personal cleanliness, and health be observed wherever milk is handled? Are fly screens essential for the dairy buildings?

28. In the process of production, what by-products tend to create an undesirable environment in the stable? What problems are created by the handling of raw products (feed)? By bacterial development?

29. Frequently repeated operations make efficiency important in industry. Does this apply to the dairy enterprise? Illustrate.

30. Any investment made in a business enterprise should bring a financial return on the investment. Does this statement apply to the dairy buildings? To the automobile on the farm? To a modern home?

31. The milk ordinance in many sections calls for 3 sq. ft. of glass area per cow, or adequate supplementary artificial lighting. Why is such importance given to lighting? Would all artificial light and no windows meet the requirements?

CHAPTER IX

TYPES OF DAIRY BARNS

There are two general types of dairy barns. In one a stall is provided for each cow, in which she is fed, watered, and milked. She is kept in her stall at night and for at least a part of the time on stormy days. This barn is called the *individual-stall type*. In the second barn the cows are allowed to move about at will. Some dairymen divide the barn into pens for four or more cows to facilitate handling and to secure a better grouping of cows for other reasons. This barn is known as the *loafing type*.

32. Individual-stall Barn.—The most common plan for the individual-stall barn provides for the storage of hay, bedding, and perhaps ground feed and oil meal on the second floor. This plan of overhead storage has two advantages: (*a*) it stores the materials where they will be most convenient for use, and (*b*) it greatly reduces roof area of the barn, which, of course, reduces the cost of this item. Sufficient strength, however, must be built into the barn frame to support the additional weight of materials stored overhead.

TABLE 17.—LENGTH OF CHORE ROUTES

Arrangement	Chore route, feet per stall			
	Feeding	Milking	Manure removal	Total
Face in	16.5	10.5	8.3	35.3
Face out, no driveway	26.1	9.8	7.1	43.0
Face out, with driveway	25.5	9.5	3.7	38.7
Mangers across length of barn	27.8	9.5	8.3	45.6

With the new practices of chopping and blowing hay into buildings and the new types of storage structures available, there is a tendency to build one-story barns with feed storage adjacent. The decrease in the fire hazard secured by the use of one-story barns is a factor in its favor.

Arrangement of Stalls.—In arranging the floor plan, the cows may be faced into a central feeding alley, they may be faced out from a central service alley, or they may be grouped with mangers running across the length of the barn. Each of the plans has advantages. The face-in plan reduces the chore route for feeding and allows more sunshine on the gutter and stall floor. The face-out type avoids division of the herd when they are stabled; it decreases somewhat the chore route for milking; it makes possible a little more convenient arrangement of hay chutes; and it is often considered to have an advantage in showing off the herd. Attention is directed to a study of 100 dairy barns in Wisconsin, made with a view to determining the relative desirability of the different plans or arrangements.[1] In this group 70 barns were planned for the cows to face out, 11 to face in, and the remainder were arranged with mangers running across the length of the barn. The length of chore routes for the operations of feeding, milking, and manure removal were checked and are given in Table 17.

TABLE 18.—DIMENSIONS FOR STANDARD STALL DESIGN

Breed	Stall length	Stall width
Holstein, large	5 ft. 8 in.	4 ft. 0 in.
Holstein, small	4 ft. 10 in.	3 ft. 6 in.
Ayrshire, large	5 ft. 6 in.	3 ft. 8 in.
Ayrshire, small	4 ft. 6 in.	3 ft. 6 in.
Guernsey, large	5 ft. 4 in.	3 ft. 6 in.
Guernsey, small	4 ft. 6 in.	3 ft. 4 in.
Jersey, large	5 ft. 0 in.	3 ft. 6 in.
Jersey, small	4 ft. 4 in.	3 ft. 4 in.

Stall Design.—Next in the problem of planning comes the selection of proper size of stall. The dimensions for dairy-barn stalls shown in Table 18 have been found to be satisfactory. In every herd there are cows of different sizes, and there are two methods of taking care of this variation. The gutter may be set at an angle with the manger curb, making a long stall at one end of the barn and a short one at the other, with variable lengths between; or stalls may be made the same length and an adjustable

[1] WHITE, H. B., Dairy Barns from a Manufacturing Point of View, *Agr. Eng. J.*, Vol. 10, No. 4, p. 117, April, 1929.

stanchion used. This type of stanchion may be moved toward the gutter or away from it, as the need may demand.

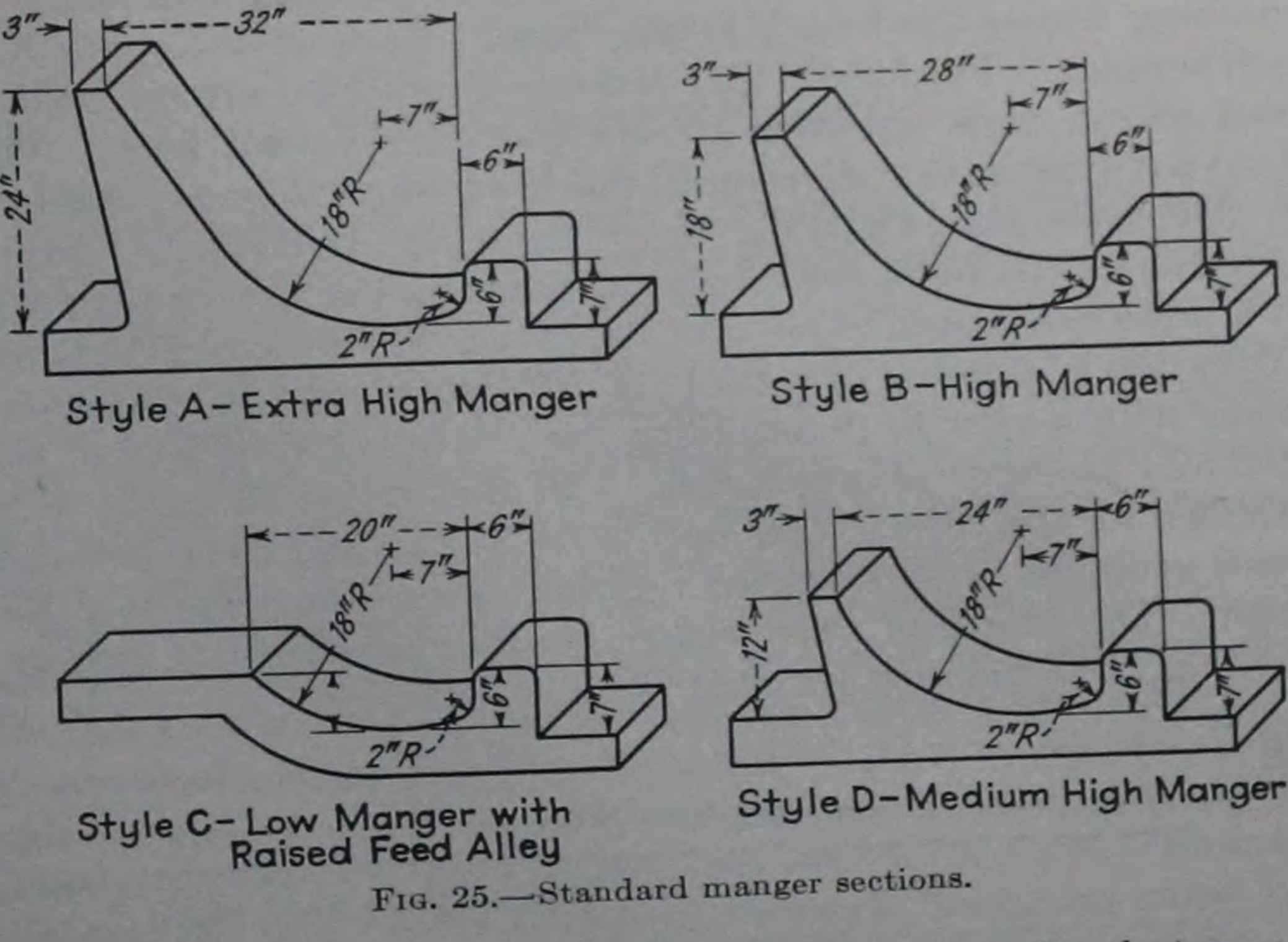


FIG. 25.—Standard manger sections.

The size of manger has been standardized in order that manufacturers of manger dividers and other equipment may be able to

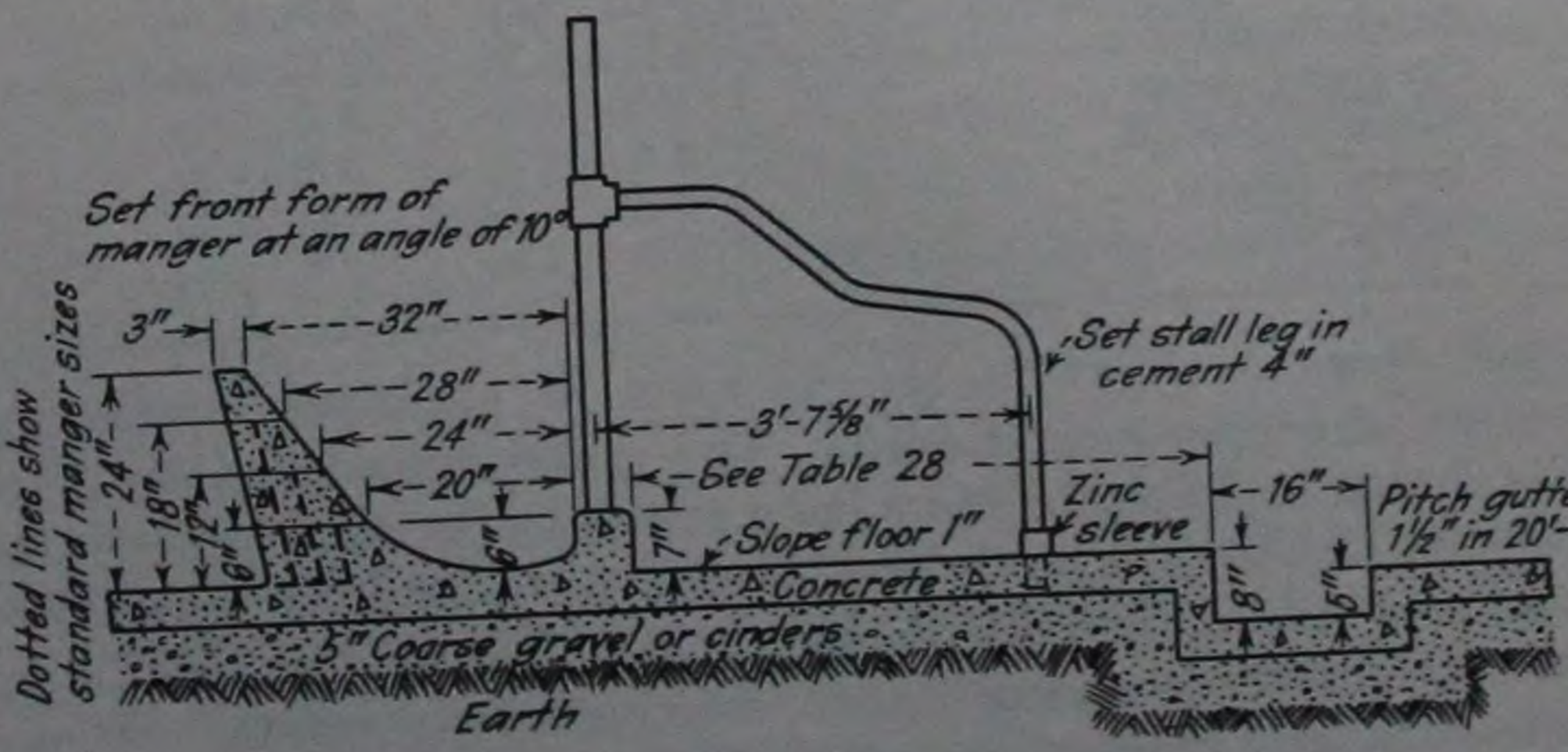


FIG. 26.—Standard stall and manger design.

supply farmers with this equipment at reasonable prices. Figures 25 and 26 show the standards that govern most manufacturers.

After the stall length and manger design have been determined and the width of feed and service alleys decided on, the width of the barn can be computed. A satisfactory width seems to be 34 ft., although some persons prefer 36 ft. in order to have a little more room for chore operations. The 34-ft. width has some advantages in economy of construction of roof and framing and therefore warrants some sacrifice in convenience.

The length of the barn will be determined by the number of stalls, the number and width of cross-alleys needed, the number of calf pens and maternity pens, and the storage space required on the ground floor. In the general plan of herd improvement it is considered desirable to keep 1 calf out of 5. Stalls for 18 cows are used in the barn shown in Fig. 26, because this is considered to be the smallest size of herd for economy and because it is the maximum number one man can handle efficiently. The barn with 18 standing stalls should provide for 3 calves and 3 yearlings. The 3 two-year-olds can be alternated with the dry cows in standing stalls and maternity pens. One maternity pen should be provided for each 6 to 8 cows, making two or three such pens necessary with this size of herd. A room on the first floor should be provided for the storage of feed carts and other equipment. Chutes from overhead bins may be extended into this room for convenience in loading feed carts. The milk ordinance will not permit the hay to be thrown down into the milking barn unless a dust-proof hay chute is provided. Such construction is not desirable in the milking barn, and thus it is often built into the section containing calf and maternity pens, where the dust is not so objectionable. In locating hay chutes, the total distance that hay must be moved in the mow and on the first floor should be considered, although the requirements for sanitation are of first importance.

The barn in Fig. 27 is the conventional two-story type with feed storage on the second floor. This barn is 34 by 66 ft. and provides 18 stalls, 3 maternity pens, and 1 calf pen for 6 calves. Storage is provided for 40 tons of hay, 10 tons of bedding, 1 carload of oil meal weighing 20,000 lb., 300 bu. of corn, and 320 bu. of oats. Bins are also provided for a 2 weeks' supply of ground feed. A silo 12 by 30 ft. provides succulent feed for the winter feeding period. The windows furnish 3 sq. ft. of glass area per cow. A single-stack King system of ventilation is

planned. The size of the stack is 30 by 30 in. Six automatic fresh-air inlets are used to distribute fresh air. In warm weather additional fresh air can be secured through the windows. Walls are sided with vertical barn siding and the cracks covered with metal bats. Walls are covered with paper and ceiled inside. Paper and ceiling on the underside of the mow-floor joists meet

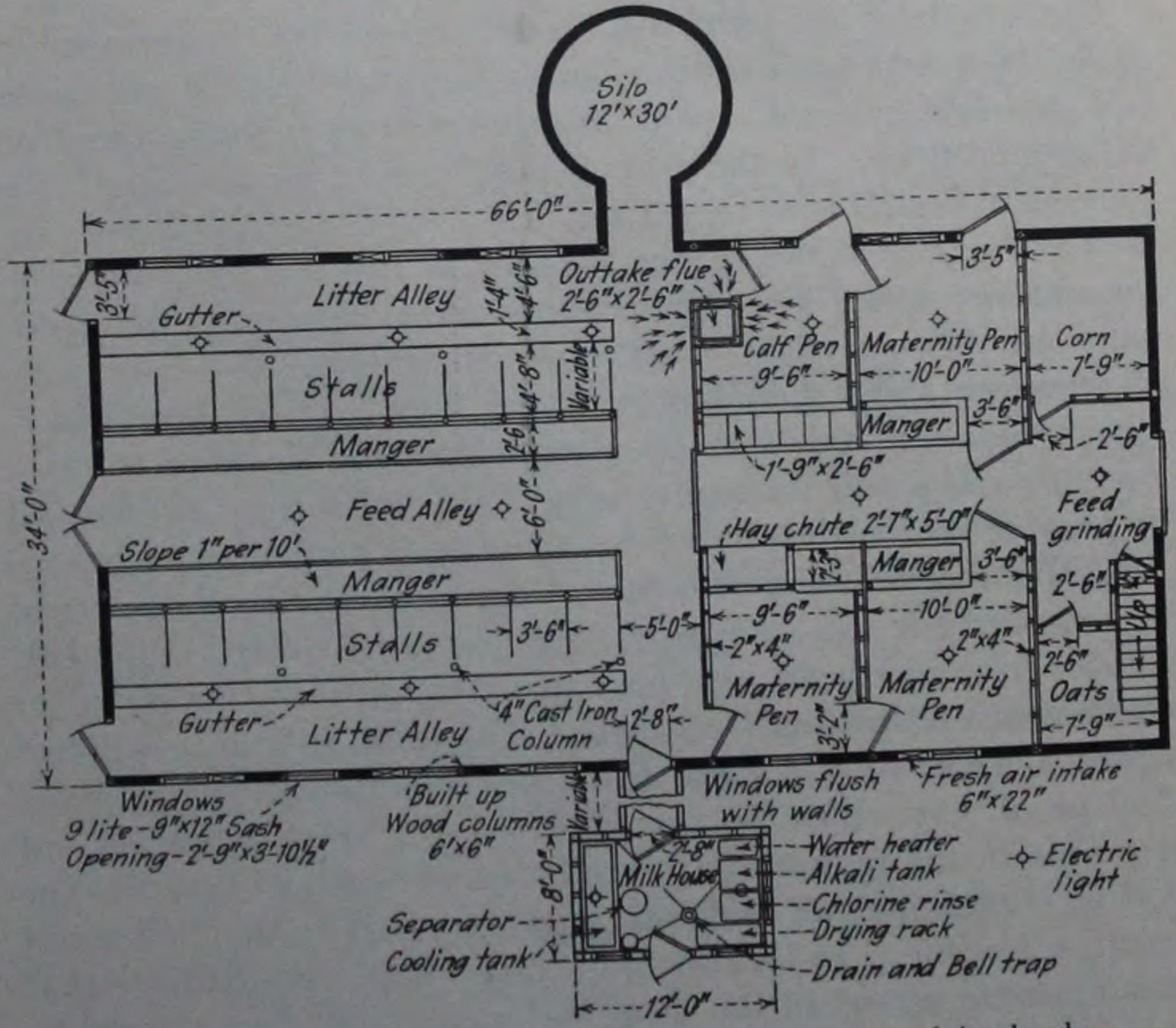


FIG. 27.—Conventional-type dairy barn for one-man dairy herd.

the requirements for sanitation and for warmth. Steel stanchions and stalls are used in milking and calf barns.

The feed-grinding room is placed in the central hall on the lower floor so that a tractor may be belted to the grinder when desired. Oats and corn are shoveled to the grinder and the ground feed delivered upstairs to storage bins. Oil meal is stored on the second floor in an area especially constructed for it. A mixing floor next to the ground-feed bins and convenient to the mixed-feed bin adds to the convenience of this part of the work.

The hay storage in the barn illustrated in Fig. 28 extends to the ground, and the stalls, pens, and feed storage are all on the ground floor. The capacity is practically the same as for the

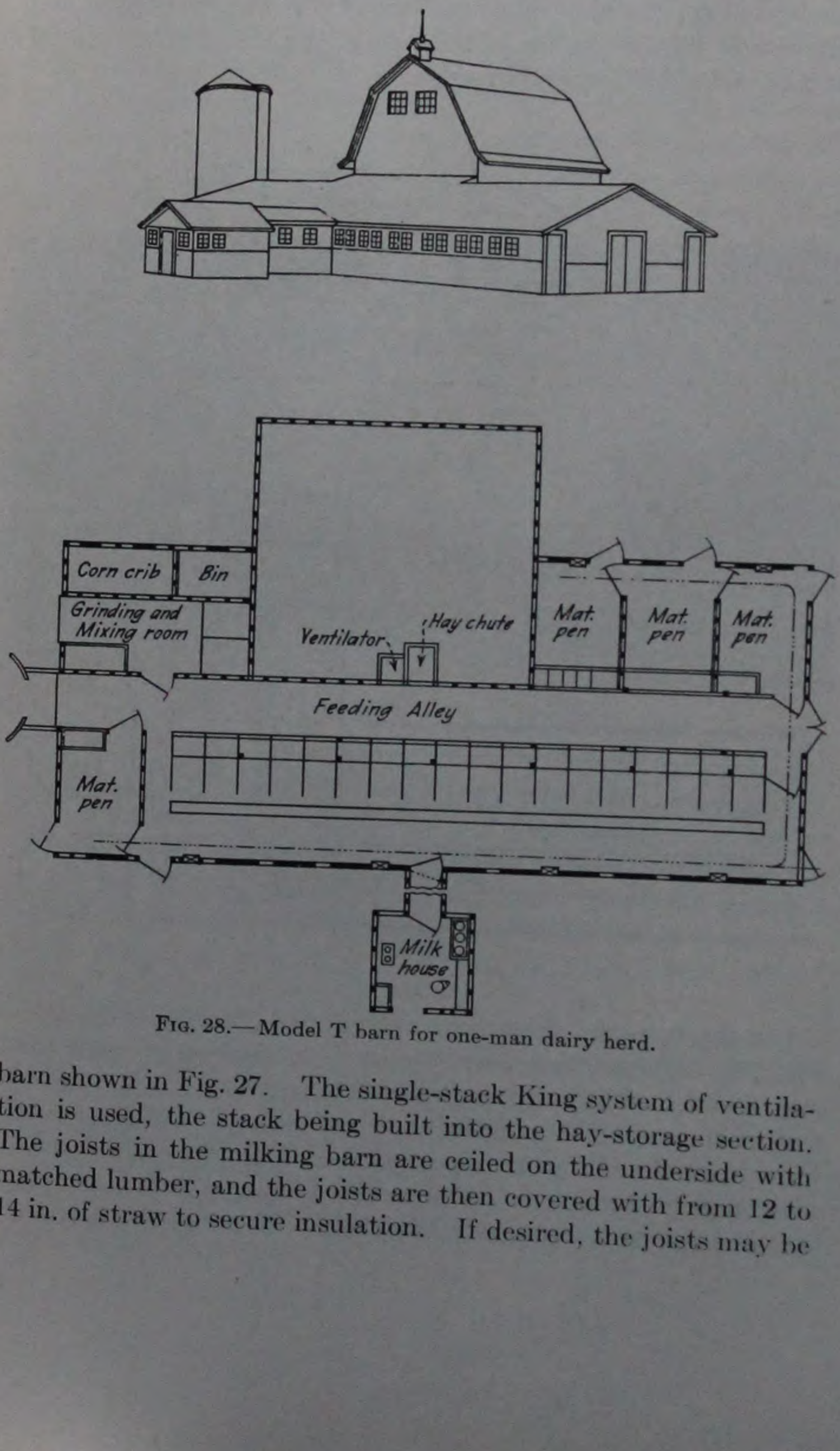


FIG. 28.—Model T barn for one-man dairy herd.

barn shown in Fig. 27. The single-stack King system of ventilation is used, the stack being built into the hay-storage section. The joists in the milking barn are ceiled on the underside with matched lumber, and the joists are then covered with from 12 to 14 in. of straw to secure insulation. If desired, the joists may be

covered with insulating board. This barn can be constructed of lighter weight material, but the larger amount of roof surface and the added foundations bring the cost up to nearly the same amount as for the plan shown in Fig. 27. If hay is chopped and blown into storage the size of this part of the barn can be reduced at a considerable saving in money.

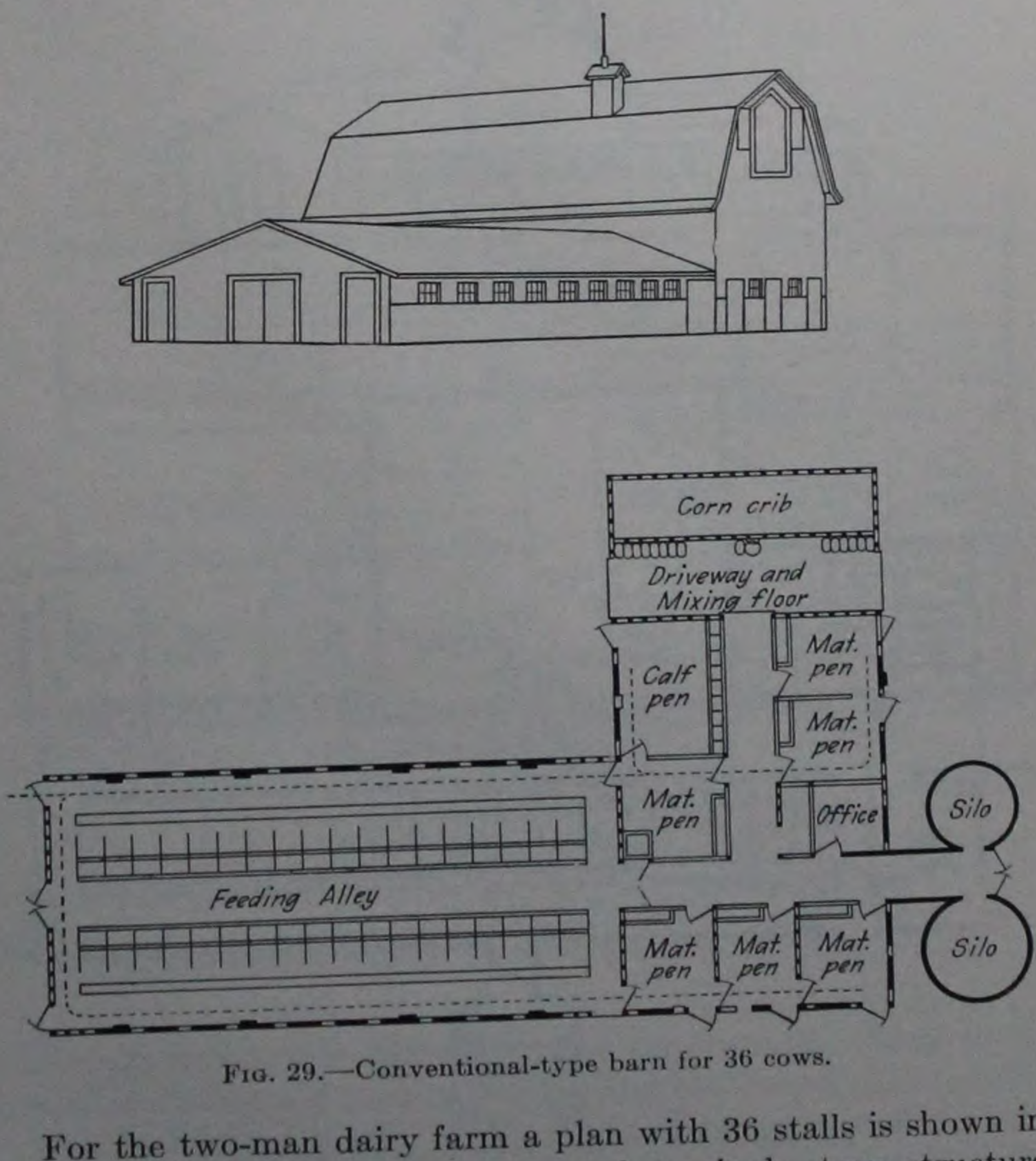


FIG. 29.—Conventional-type barn for 36 cows.

For the two-man dairy farm a plan with 36 stalls is shown in Fig. 29. The milking barn proper is a single-story structure making an L addition to the two-story barn where feed is stored and where calf and maternity pens are located. An elevator is provided for handling the corn and oats. A winter and a summer silo completes the setup. A single-stack King system of ventilation is used with automatic air inlets. Wall construction and

ceiling insulation are similar to that used in the barn shown in Fig. 28. Feeding alleys are made as straight as possible to facilitate the use of feed carts or carriers.

33. The one-story barn has a number of points in its favor. The fire hazard is reduced, the construction can be very materially lightened, and sanitation is made less difficult. Dairymen who have herds that have been built up over a long period of years are especially interested in this type of structure from the standpoint of safety alone. Several disastrous fires are on record that destroyed herds of cows and with them the accumulated

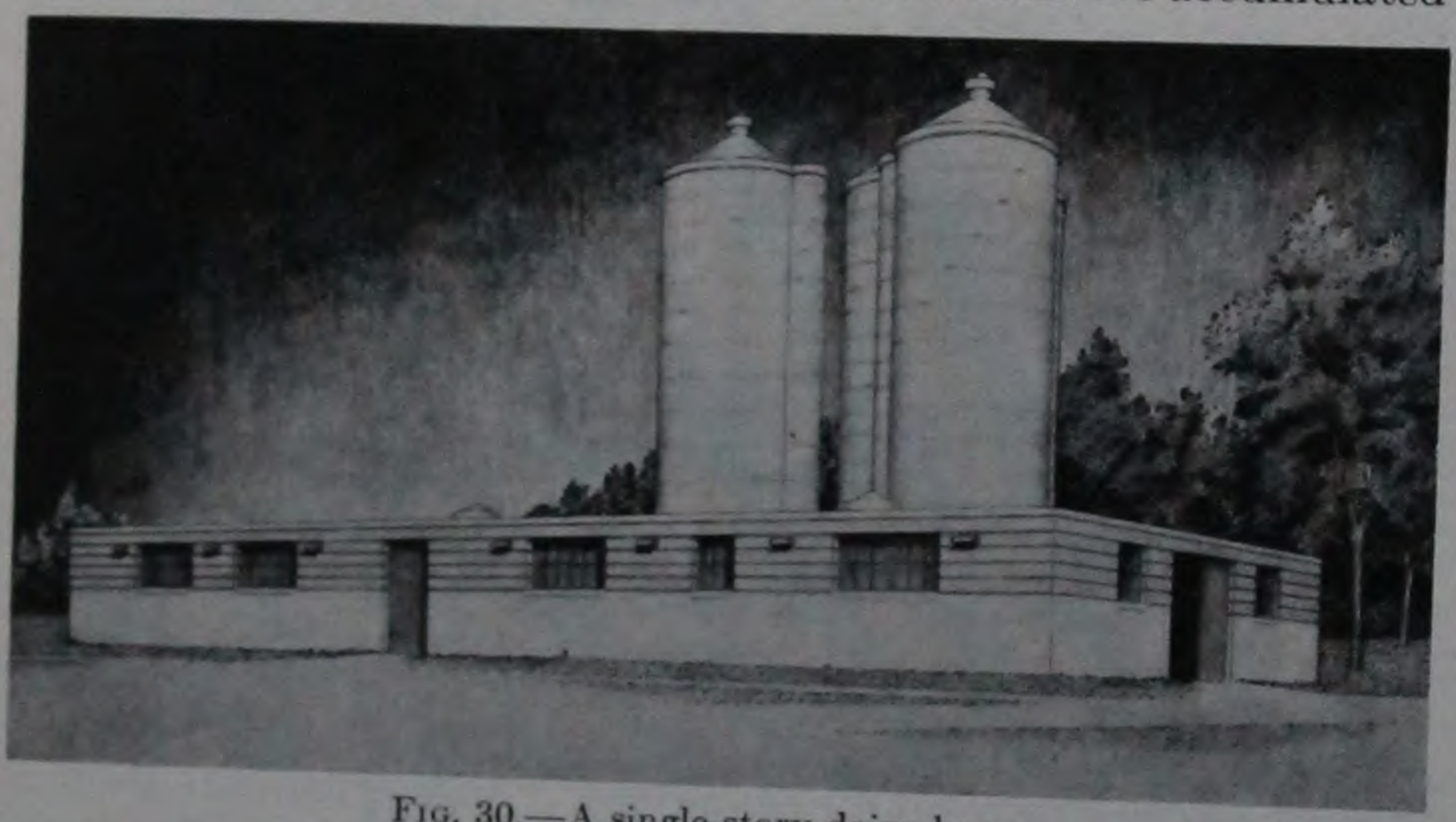


FIG. 30.—A single-story dairy barn.

value of a lifetime of careful selection and work. Many two-story barns are built to support the weight of 100 tons or more of hay. By relieving the structure of this load, much lighter framing materials may be used. The additional hay-storage structure may be designed to meet the very simple requirements for keeping hay at a much reduced cost as compared to second-story barn space. Figure 30 shows a single-story barn built of concrete having silos and a hay keeper adjacent.

34. The loafing barn has some advantages and some disadvantages when compared to the conventional type of barn. One of the greatest advantages is that a high-quality product may be produced with a smaller investment in equipment. This is especially true where the farmer has barns already built that will not meet the requirements for high-grade milk production but that will house the herd comfortably as a loafing barn. In

such a case the only new construction for the enterprise would consist of a combination milkhouse and milking room. A second advantage comes from the freedom that the cows are afforded. It has been proved conclusively that cows fall off in production when they are confined in stanchions. Some dairymen report that cows can be kept cleaner in the loafing barn than in other types of barns, which is a third factor in favor of this type. A fourth advantage is that the labor of cleaning the barn is reduced and is spread over the day. The milking unit must, of course, be kept clean at all times, but it is small, and, since cows are kept in the stalls but a short time, this is not difficult to accomplish. The loafing shed can be cleaned and bedding supplied during the day when other work is not pressing. Some dairymen object to the loafing barn on the premise that much additional bedding is

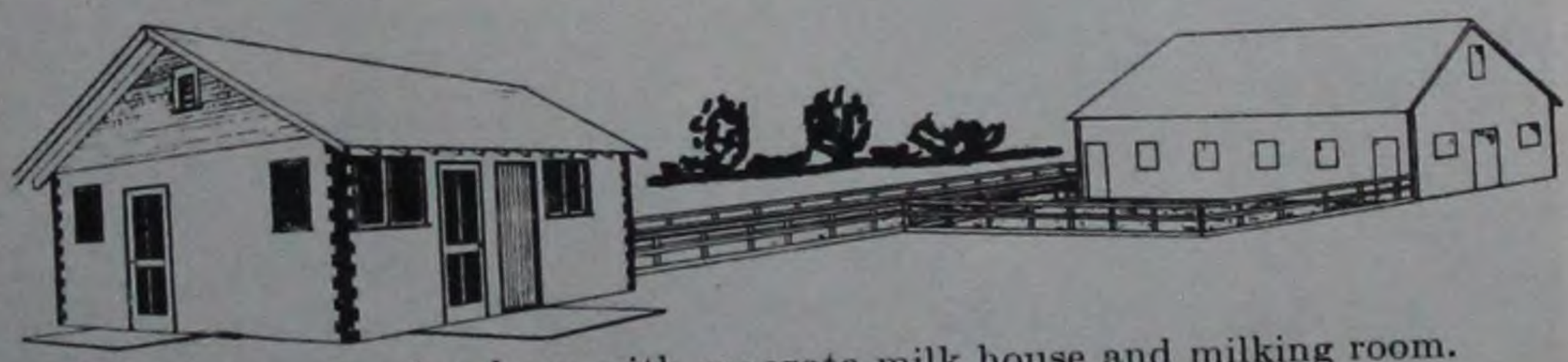


FIG. 31.—Loafing barn with separate milk house and milking room.

required. Where a farmer has an abundance of straw and wishes to get it changed into manure, this increase in use of bedding will not be an objection but an advantage. Additional barn room is required, but since a lower quality structure will serve this is not a serious objection. Some designers allow 50 sq. ft. of loafing space per cow where exercise yards are easily accessible, and 75 sq. ft. per cow where no outside yards are available or where the barn must be closed.

35. The milking room is sometimes made large enough to hold a fourth of the herd so that only four changes will be necessary at each milking. In other cases four stalls are considered sufficient. Where a mechanical milker is used two cows may be brought in at a time. The cows can be fed and cleaned and the milker attached. Two more may be admitted, fed, and cleaned. The milker can then be transferred to these cows, the first two stripped and turned back to the loafing barn. Two more cows are then admitted and the process repeated. After a few days the cows come into the milking room without trouble or loss of time. When cows have been fed concentrates and milked, they

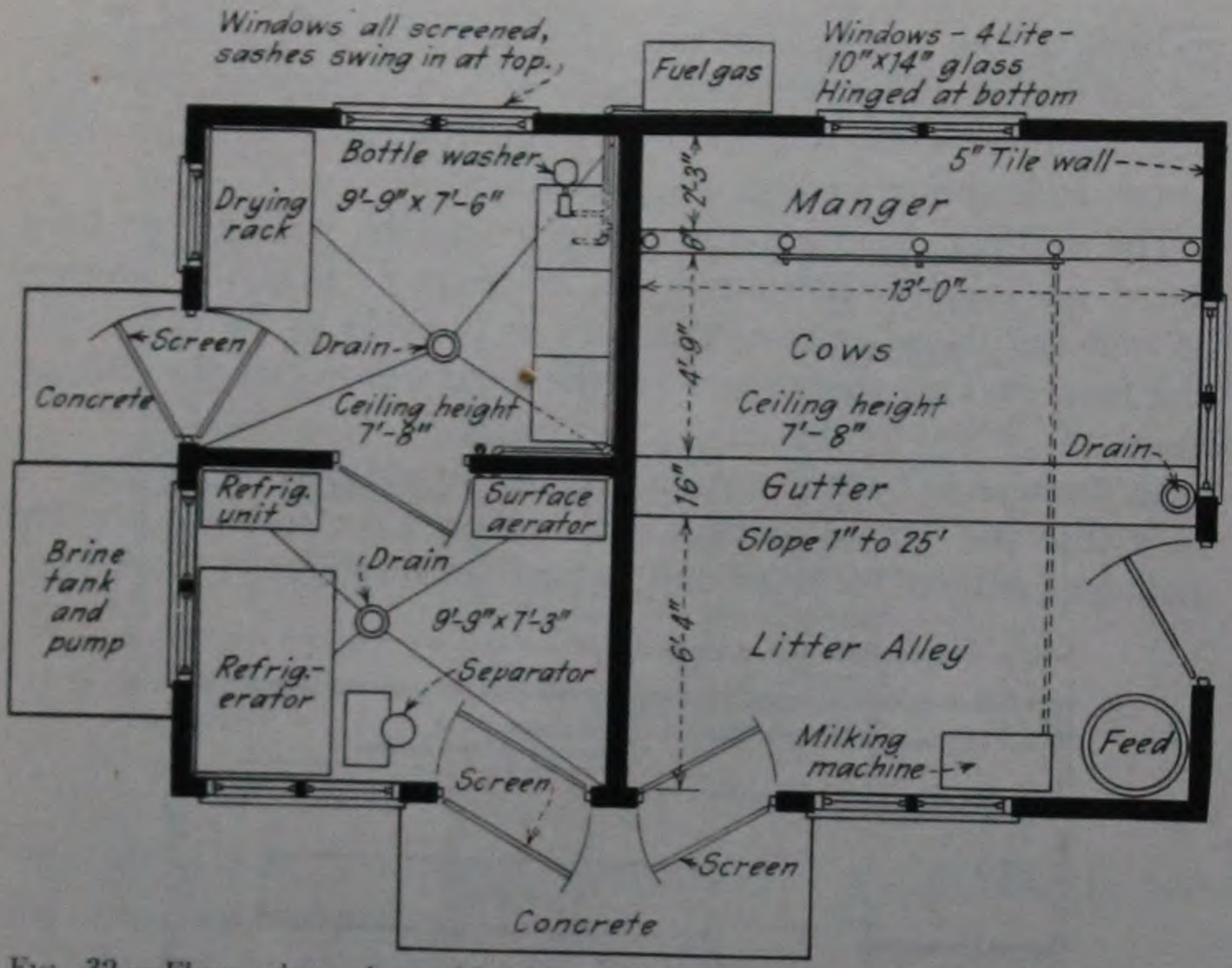


Fig. 32.—Floor plan of combination milkhouse and milking room shown in Fig. 31.

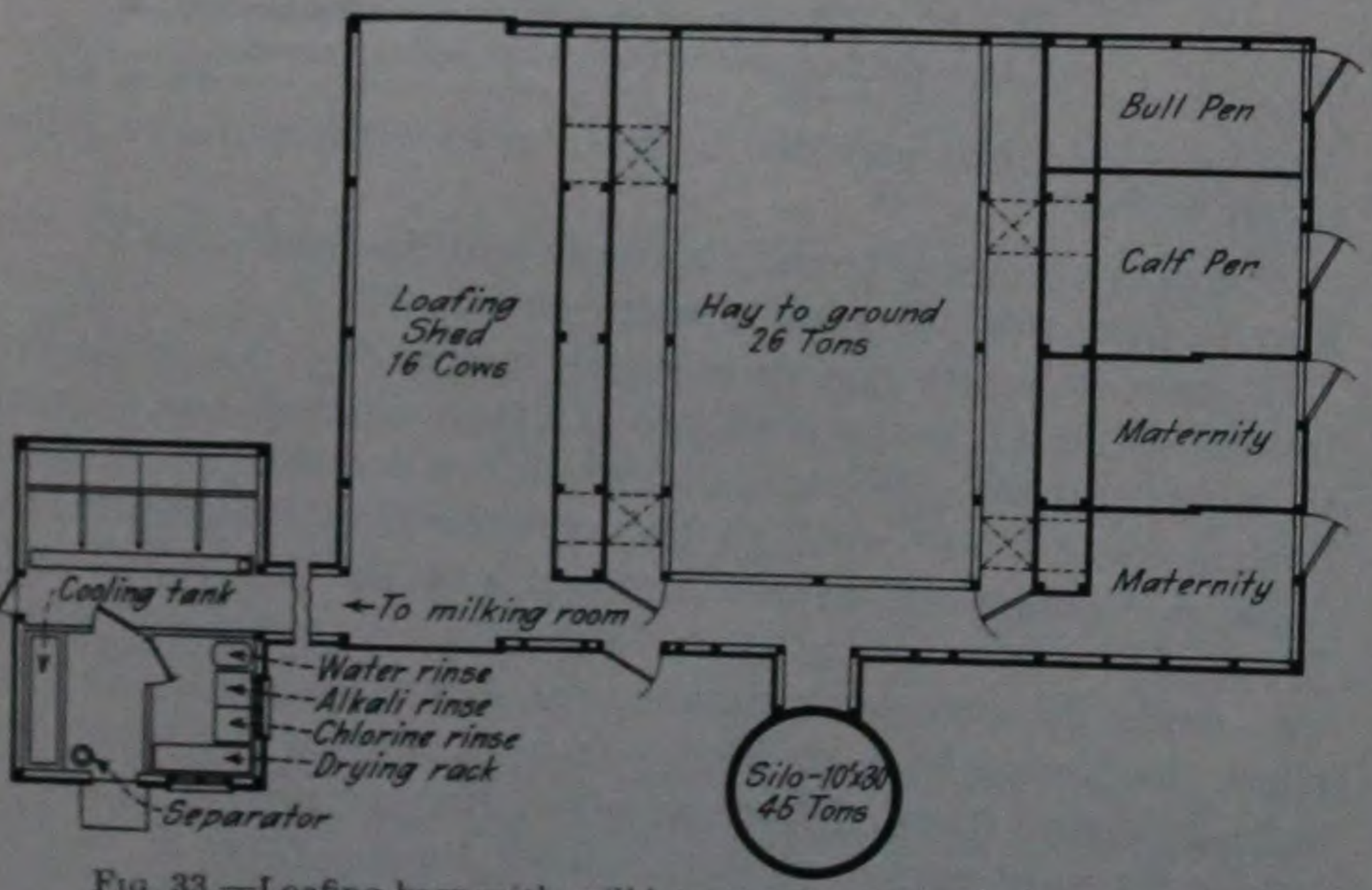


Fig. 33.—Loafing barn with milkhouse and milking room attached.

go back to the loafing shed and give no trouble by coming up a second time. Where the milking room is in a separate structure, it is often advisable to combine the milking room with the milkhouse, as is shown in Figs. 31, 32, and 33.

The milking room may be connected to the loafing barn by a closed passageway if desired. It is desirable that this passage be well ventilated but kept as dark as possible to aid in keeping flies from making their way from the loafing barn into the milking room.

In the loafing barn shown in Fig. 34 the width of hay storage is such that the 3 ft. of manger space allowed per cow will provide sufficient storage for loose hay to feed her throughout the season.

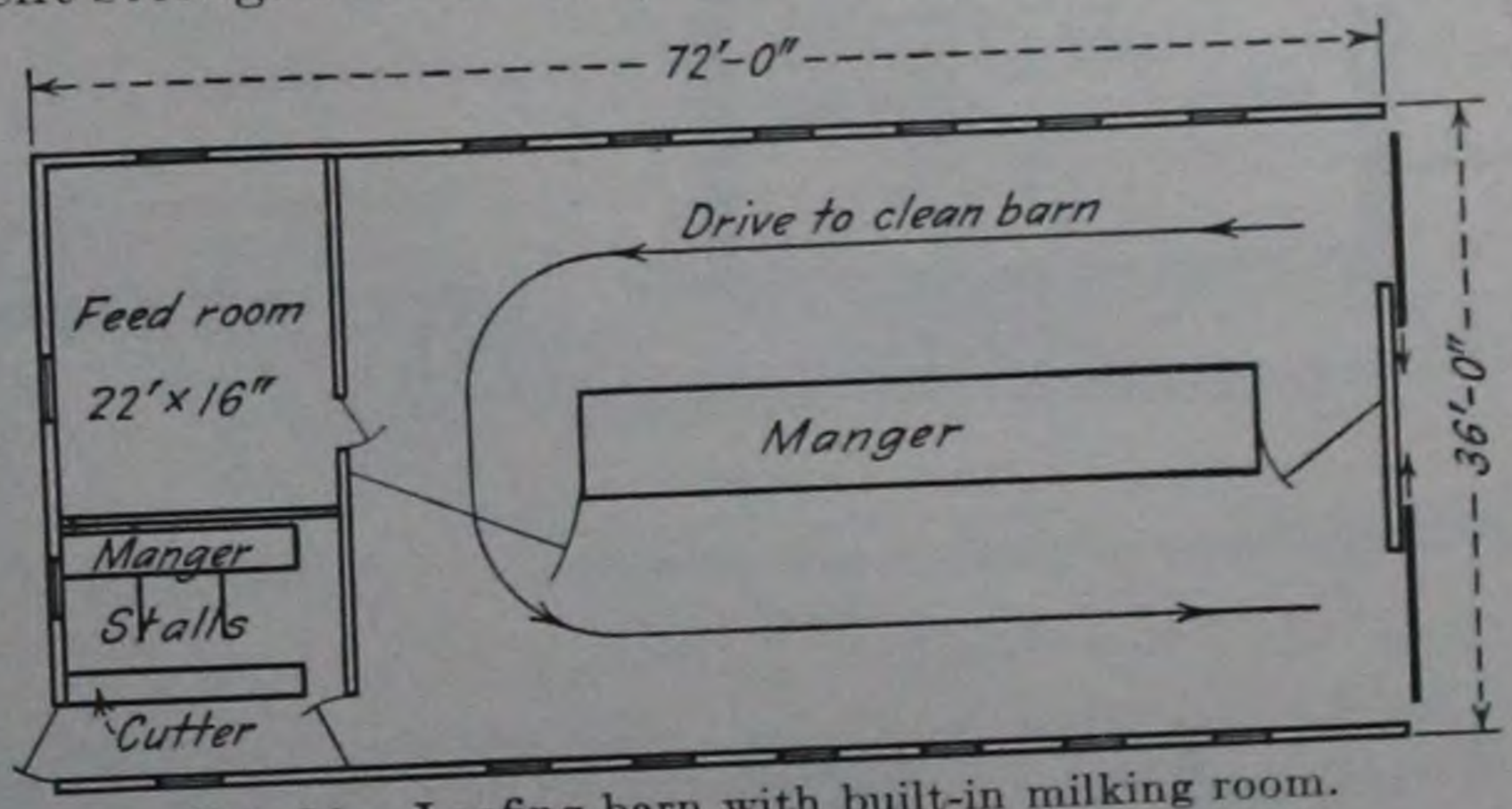


FIG. 34.—Loafing barn with built-in milking room.

The barn can thus be fitted to the size of herd by varying the length.

In colder climates the milking room and the milkhouse as well may be built into the loafing barn (see Fig. 34).

A more elaborate system is shown in Fig. 35. The cows are brought from the loafing shed two at a time, cleaned, and allowed to move into the milking stalls, which are arranged in tandem. Such a system will work to best advantage with large herds.

36. A Comparison of the Loafing and the Individual-stall Types of Barns.—A time study extending over a 2-week period was made on two dairy plants near Columbia, Mo. In one plant the loafing-barn method was used, and in the other the individual-stall barn. There are some discrepancies in the data, but for the most part the results indicate the difference in the two methods fairly accurately (see Table 19). For example, the cows in the standard barn were brushed longer than those in the

loafing barn, accounting in some measure for the extra labor. The cows in the individual-stall type would sometimes lie down while waiting to be milked, making a second cleaning necessary.

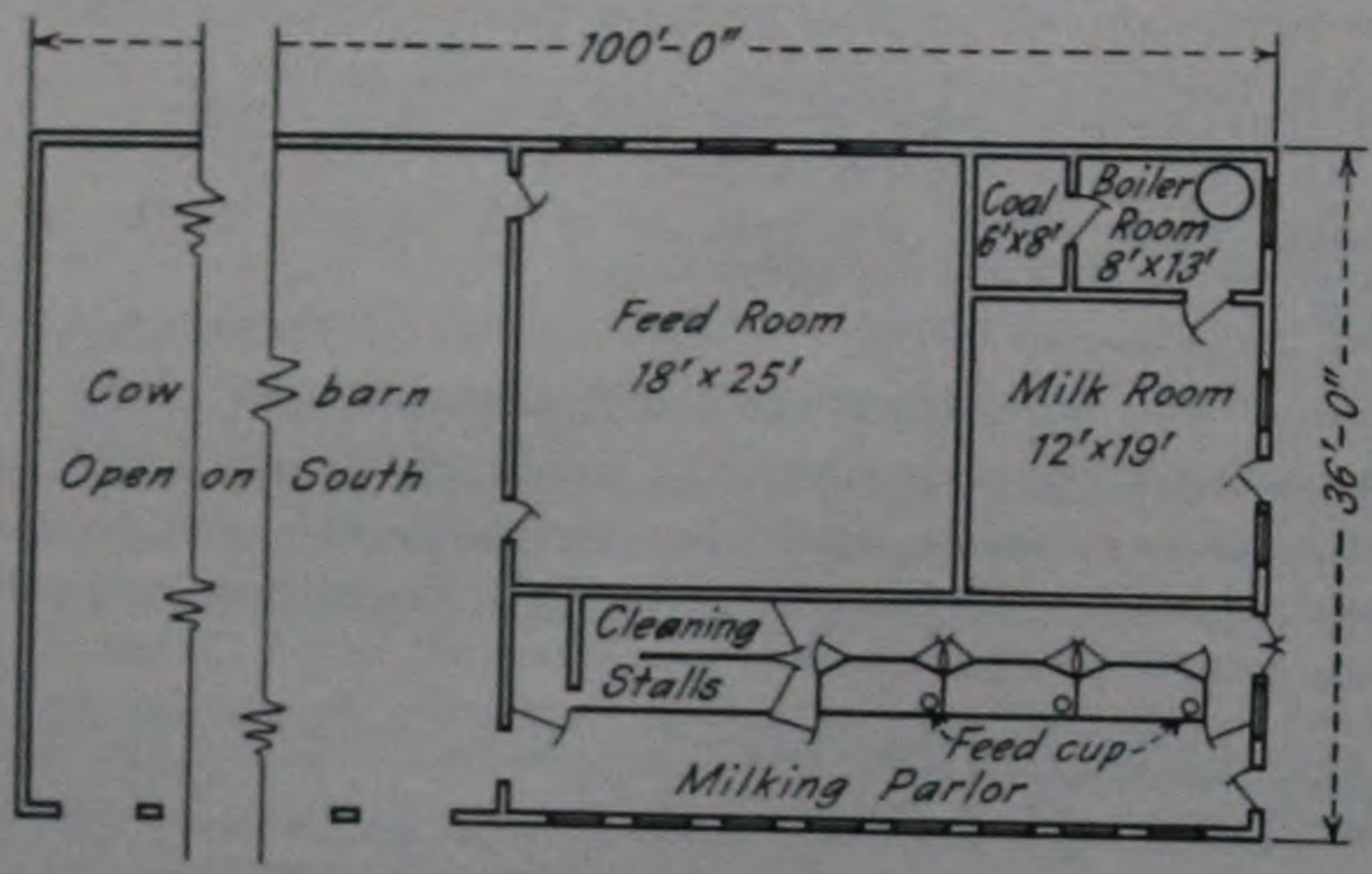


FIG. 35.—Tandem arrangement of milking stalls.

Disposal of milk in the large standard barn required more travel and thus required additional time.

The question has arisen as to whether the cows have time to eat their concentrates in the loafing-barn system. The cows are

TABLE 19.—TIME PER COW PER MILKING
In Minutes

	Standard dairy barn	Loafing barn, milking parlor
Stabling	0.21	0.23
Feeding	0.43	0.18
Cleaning cows	1.87	0.77
Milking and disposing of milk	4.2	2.9
Turning cows out	0.1	0.17
Cleaning stable or milking parlor	1.03	0.23
Cleaning loafing barn		1.25
Total	7.84	5.73
Gallons milk per cow	1.18	1.55

placed in the milking stalls in pairs, and since the time per cow was 5.7 min., each cow had 11.4 min. in which to eat her concentrates. Cows giving more milk required longer time in the stalls and consequently had more time in which to eat the extra concen-

trates needed. It was the herdsman's opinion that the cows seemed to have ample time in which to eat their concentrates while they were being milked.

Cows accustomed to the milking parlor stand outside, ready to come in for feed and milking, and consequently no time is lost in the process of changing cows. This system is being used to advantage with small as well as with larger herds in many localities.

Questions and Problems

32. Some dairymen in the Northern states are of the opinion that the loafing type of dairy barn is not adapted to their section of the country. Is there good reason for this belief? How do the loafing barn and individual-stall barn compare as to required floor space per cow? What advantages are offered by the pen type of loafing barn over the regular loafing type where cows are all together?

33. The belief prevails in some quarters that the one-story type of dairy barn will be the more common type in the future. What are the factors that will determine this?

34. The use of the loafing barn is growing in Missouri. Why is this true?

35. What are the different details that must be given consideration in making the floor plan for an individual-stall dairy barn?

36. In some plans for the milking room the milking stalls are arranged in tandem. Does this have any advantage over the regular arrangement? The number of stalls in the milking room varies from 2 to 12. Which is to be preferred?

37. What are the advantages and disadvantages of placing the milking room and the milk room in the same structure as the loafing and feed space?

38. Make a ground-floor plan for a loafing barn for 24 cows, hay to be stored overhead. Use a scale $\frac{1}{8}$-in. equals 1 ft.

39. Make a floor plan for a milking room and milk room combined to be used with the loafing barn.

CHAPTER X

BUILDINGS FOR THE POULTRY ENTERPRISE

Poultry is one of the common enterprises on most farms. Flocks vary from 50 hens, kept to supply the family needs, to 500 or more, where poultry raising is a major enterprise of the farm. Flocks between these limits in size are considered to be uneconomical. Intermediate numbers require almost as much attention as the larger flocks and bring in a relatively decreased return.

Buildings for the poultry enterprise consist of the laying house, the brooder house, the range shelter, and perhaps a small structure for the storage of eggs.

37. The laying house should be planned to meet three requirements: the comfort of the hens in both summer and winter, the convenience of the operator, and the financial limitations of the enterprise. Failure in any one of these requirements limits the success of the poultry project.

In planning for the comfort of the hens, three situations should be provided for: the roosting, the feeding or exercising, and the nesting of the hens. The conditions for comfort may be different in each of these situations, but in all will be found the requirement of the proper temperature, humidity, and air movement. A better picture of the problem may be secured by an analysis of comfortable conditions for homes, factories, etc. People avoid sitting or sleeping in a draft because they may contract a cold or pneumonia; the same persons, however, may work without discomfort in the wind or in a shop where air is moving rapidly. Air currents are called *drafts* when they cause too rapid cooling of the body. Thus it is seen that a certain degree of air movement may be called a draft in one instance and not in another. It would seem logical that greater care should be exercised to meet the requirements for comfort in the roosting section than in the feeding room or scratch shed. Probably no definite temperature, humidity, or air movement can be specified as the most desirable, but considerable work has been done that will aid in setting up limits for each.

An experiment was conducted at Iowa State College several years ago in which 10 hermetically sealed coops or pens were used. Each of these coops held 10 hens, and each received a definite amount of air: the first pen received an amount so small that the question was raised whether the hens would live at all, and the last pen received an amount far in excess of the needs of the hens. The coops were set up in a room that was held at a uniform temperature throughout the winter. There was little variation in production in the different coops, although the humidity varied from very low to a condition where the litter, the feed, and the hens were covered with moisture. One year's observation of these experimental hens after the close of the experiment revealed no bad effects.

At the Missouri Experiment Station an experiment is being conducted in which very little attempt is made to control temperature. The house is left open on all four sides for a distance of 3 ft. 6 in. above the ground. The remaining distance of 1 ft. 6 in. to the plate level is sided. A metal roof placed on strip sheathing is used. The underside of the rafters is covered with shiplap, and the space between is filled with straw to serve as an insulator. Nests and roosts with tight dropping boards were built into this insulated part of the building. During stormy periods in winter one thickness of burlap is stretched around the building to prevent snow from drifting in. The free circulation of air in the lower half of the building keeps the humidity to as low a point as it is outside. The temperature has been slightly higher in the roosting section than outside, but otherwise it followed all the changes taking place outside. Slightly higher production has been secured in this house than in any others on the poultry farm. No trouble has been encountered with disease; the two seasons through which this house has been operated, however, have been very favorable. The hens in this experimental house spent most of the daytime on the ground floor in the open section, even on cold, windy days.

Watering is a problem when feeding quarters are cold; but this problem may be met by the use of water heaters or insulated containers.

38. Nests, as well as roosting sections, should be made comfortable for hens. Nests should be free from drafts in winter and should be ventilated so as to be comfortable in summer. A

checkup on mortality in hot weather revealed the fact that of the hens that died, many were found dead on the nests. Many nest sections are made so that there is little chance for circulation of air in them, and on summer days they may be extremely hot. Wire floors in nests are used to aid in keeping nests clean and also to provide for some air circulation in summer. The amount of material in the nest can be varied to suit the needs at different seasons. Consideration must be given to summer as well as to winter conditions in planning the nest section as well as other parts of the house.

Missouri Experiment Station Bulletin 247 reports experiments on growth of chickens. It was shown in this circular that the rate of growth was materially reduced when the temperature exceeded 85°F. Likewise, production records on hens show a decided falling off when laying-house temperatures exceeded 85°. Considering the other extreme, it is generally agreed that hens are thrown out of production if combs and wattles are frozen. It is not known at what temperature this occurs, but it would seem that 32°F. should certainly be the lowest limit for the roosting and nest section of the poultry house. This gives an upper as well as a lower limit in temperature for this part of the house.

39. *Relative humidity* may vary considerably so long as the temperature is kept constant, as was seen in the Iowa experiment. It seems, however, that if the temperature is allowed to fluctuate, sufficient air change should be provided to keep the relative humidity to some point below 50 per cent. Relative humidities higher than this occur in some instances without causing trouble, but when the temperature is falling the 50 per cent relative humidity often causes condensation on windows and equipment. Relative humidity must be given consideration because of the fact that the birds give off moisture through respiration. If the inhaled air is already near the saturation point it will be difficult for the birds to get rid of moisture by this method. Maintaining the proper relative humidity is largely a matter of ventilation. Some benefits, however, may be secured through the use of a straw loft, although no definite facts have been established on this question. It is a well-known fact that the introduction of dry straw into a room will lower the relative humidity very rapidly. Bedding down animals with dry straw improves conditions many times by lowering relative humidities. It is not

known how much benefit can be secured in this way from the straw loft that stays in place throughout the season, however.

If air change is to be depended on to remove moisture, it will be necessary to conserve the heat already available or increase the amount of heat. Heat can be conserved by insulating walls, ceilings, etc., and by reducing infiltration through the use of impervious wall covering or weather-stripped doors and windows. The source of heat may be supplemented by increasing the number of birds.

40. *Ventilation* in poultry houses is secured by different methods in the many different designs of buildings available. The open-front-type house is used quite extensively (see Fig. 36).

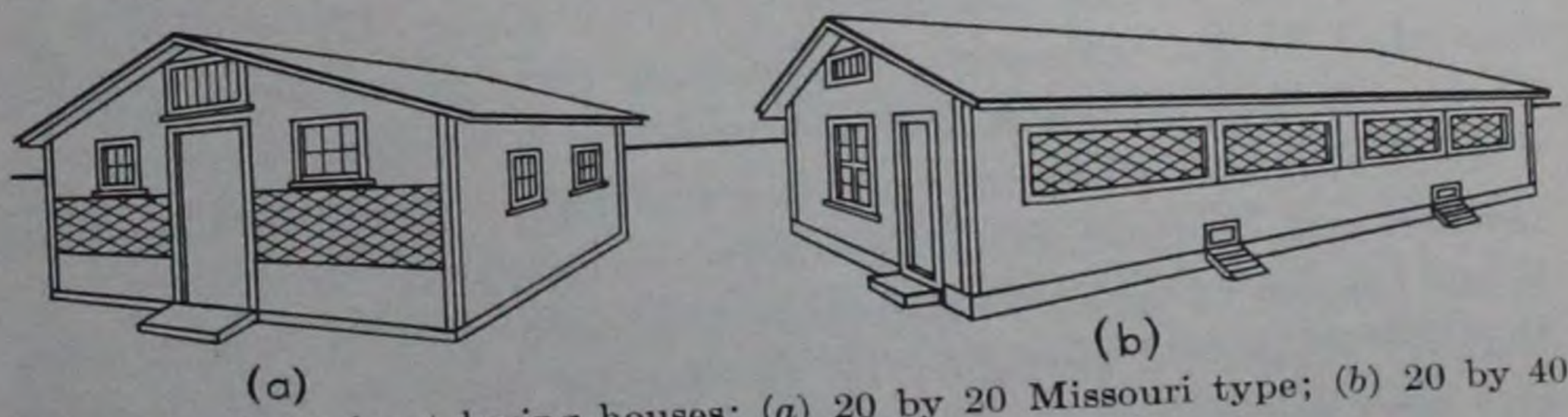


FIG. 36.—Open-front laying houses: (*a*) 20 by 20 Missouri type; (*b*) 20 by 40 Kansas type.

This type of building must have three tight sides to prevent drafts in windy weather. The roosting section is placed at least 12 ft. back from the open front, and a tight platform is placed under the roosts. The air enters and leaves through the open front, and only a limited amount of air change takes place in the roosting section. The open front allows some direct sunshine to enter the house, thereby adding to its value.

Controlled ventilation is featured in some other types of poultry houses. In these houses the walls are insulated to prevent heat loss. Special window glass is used to admit ultraviolet rays from the sun. Outtake as well as inlet flues are provided to accomplish the change of air needed to remove moisture.

41. *Convenience of the operator* rather than the comfort of the hens has been given first consideration in many poultry-house designs. In dwellings ceilings are usually placed 8 ft. 6 in. above the floors. This is about one-and-one-half times the height of the individuals who use them. If the same rule were followed for hens a ceiling height of 2 ft. would be used in poultry houses. The argument has been offered that a certain volume of air is

needed in the poultry house, thereby requiring the higher ceilings. The air problem could probably be solved, however, by more rapid changes if lower ceilings were used. As noted in Chap. XIV, the hens give off a comparatively small amount of heat. If each hen is allowed 3 sq. ft. of floor space and a 7-ft. ceiling is used, the hen must provide heat to overcome the loss through 3 sq. ft. of ceiling and her share of the walls, windows, and doors as well. In most poultry houses this would be 4.5 sq. ft. of wall plus 3 sq. ft. of ceiling, making a total of 7.5 sq. ft. If construction is such that 0.30 Btu is lost per square foot (which would be better-than-average construction) and if a temperature difference of 20° is expected, each hen would need to supply 45 Btu per hour ($7.5 \times 0.3 \times 20$) if no heat were lost in ventilation. It is seen from this case that the 20° difference in temperature cannot be maintained in the whole house, and since the roosting section and the feeding room are together in most designs, the temperature will be the same in each. If hens, like people, need different conditions at rest and at work, many poultry houses will not provide the conditions needed.

In another experimental house at the Missouri Experiment Station, an attempt has been made to design a building to suit the needs of the hens, of the caretaker, and of the budget as well. Figure 37 shows the plan for this experimental house. The roosts and nests are upstairs, and the feed and watering equipment are downstairs. The lower section has an open front on the south and has sun porches attached on each side of the south door, making it possible for the hens to get out into direct sunshine whenever they desire. The upper story is closed in winter with the exception of the 8- by 18-in. floor opening on each side of the hall that permits the hens access to the lower floor. The straw loft allows the warm, moist air to filter through into the attic. It is then removed from the building by a 12-in. ventilator placed on the roof.

The caretaker feeds and waters the hens, gathers eggs from the central hall, and at intervals of 1 or 2 weeks cleans under the roosts by working through cleanout doors provided in the outside walls. This design seems to provide proper conditions for hens without increasing the difficulty of doing the necessary chores, and it is possible that chore labor may even be decreased. With this arrangement it is not necessary to be in the pens with

the hens. This may be helpful in preventing the spread of disease and in making the work of the caretaker more agreeable.

42. *Financial Limitations of the Enterprise.*—Budget requirements must be given consideration in any building design. If 8 per cent of the gross income is a fair charge for housing, the cost of the laying house should probably not exceed 15 cts. per bird per year. Cost figures on several standard-type poultry houses are 13 cts. per bird per year. This would probably pay out for

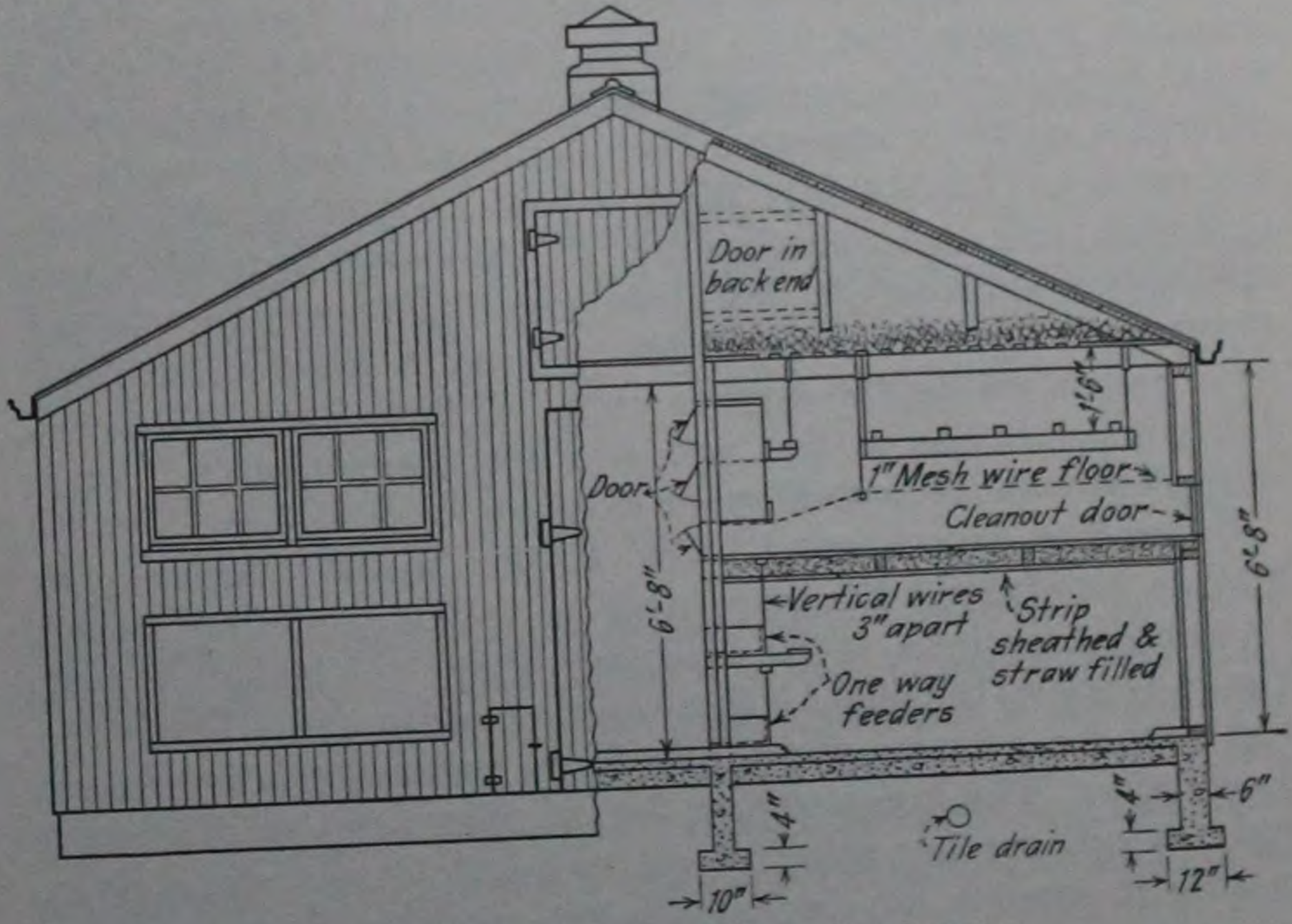


FIG. 37.—An experimental poultry house.

175-egg hens or for those of better production. The double-deck house shown in Fig. 37 holds 60 per cent more hens than the regular Missouri 20- by 20-ft. type. The extra cost of the second floor, if the quality of construction remained the same, would not cause a proportional increase in the cost of the house, and therefore it seems that this design might come within the cost required if the hens kept were good producers.

It is, of course, essential in any enterprise that cost of production be kept as low as possible so long as satisfactory returns are available. This does not necessarily imply that less money should be spent for buildings; on the contrary, it may mean that even a greater investment would be justified. The cost of pro-

ducing eggs must be divided among the following items: (*a*) depreciation of the flock, (*b*) interest on the investment in the birds, (*c*) veterinarian fees, (*d*) feed, (*e*) litter, (*f*) labor, and (*g*) housing. From studies made on some 150 farms in northwest Missouri,[1] it was found that housing cost 14.5 cts. per bird per year, which was approximately 7 per cent of the total annual cost. This shows housing to be a comparatively small item in the cost of production. No doubt there are many cases where increasing the cost might improve conditions to a point where the increase would be more than offset by a decrease in veterinarian fees, saving in feed, reduction in labor, or, possibly, by an increase in production.

Most poultry-house designs are made without regard for aesthetic considerations and, as a result, do not add to the appearance of the building group. The question of appearance is of minor importance, but it is nevertheless worthy of some consideration. A gable-roof building has some advantage in this respect, but it may be that an irregularly shaped roof can be tolerated for the additional advantage it brings in other ways.

43. The Brooder House.—To secure the best results it is necessary that chicks be hatched comparatively early in the season. To a great many poultrymen this means during the late winter and early spring months. During this time temperatures are so low that artificial heat should be supplied. The general practice has been to build a brooder house 8 by 10 ft., 10 by 12 ft., or larger, depending on the number of chicks and the length of time they are to be kept in the brooder house (see Fig. 38). These houses are built high enough so that the attendant may work in them with ease. Brooder houses may be heated with coal, oil, gas, or electric brooder stoves. Since the chicks are placed on the floor it is necessary to supply enough heat to maintain a floor temperature of at least 90° during the early part of the brooding season. Most of these heating units are provided with a cover or hood so that the high temperature needed may be secured in this area and the remainder of the house may be cooler. Such brooders are usually built on skids so that they can be moved to clean ground as desired.

[1] WOOLEY, J. C., Farm Building Studies in Northwest Missouri, *Univ. Mo. Agr. Res. Bull.* 218, August, 1934.

Outdoor Brooders.—Where electricity is available for heating an outdoor brooder is sometimes used. The one shown in Fig. 39 was used for several years at the Missouri Experiment Station. The insulated box was made so that the walls and ceiling have a conductivity value of 0.105, allowing very little heat loss. The electric heating element, as well as the fan for circulating heat, was controlled by a thermostat, so as to be automatic in operation. The chicks were allowed to run into the unheated glass-covered area at will. Special glass was used in this area in order that the chicks might have the benefit of the ultraviolet rays of the sun.

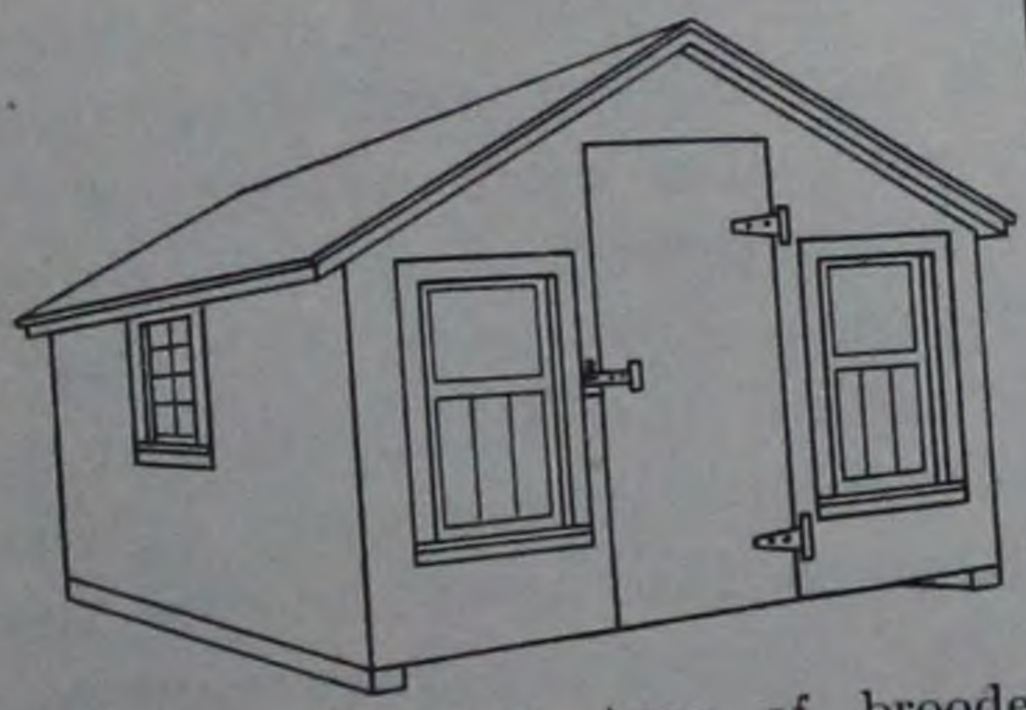


FIG. 38.—Common type of brooder house.

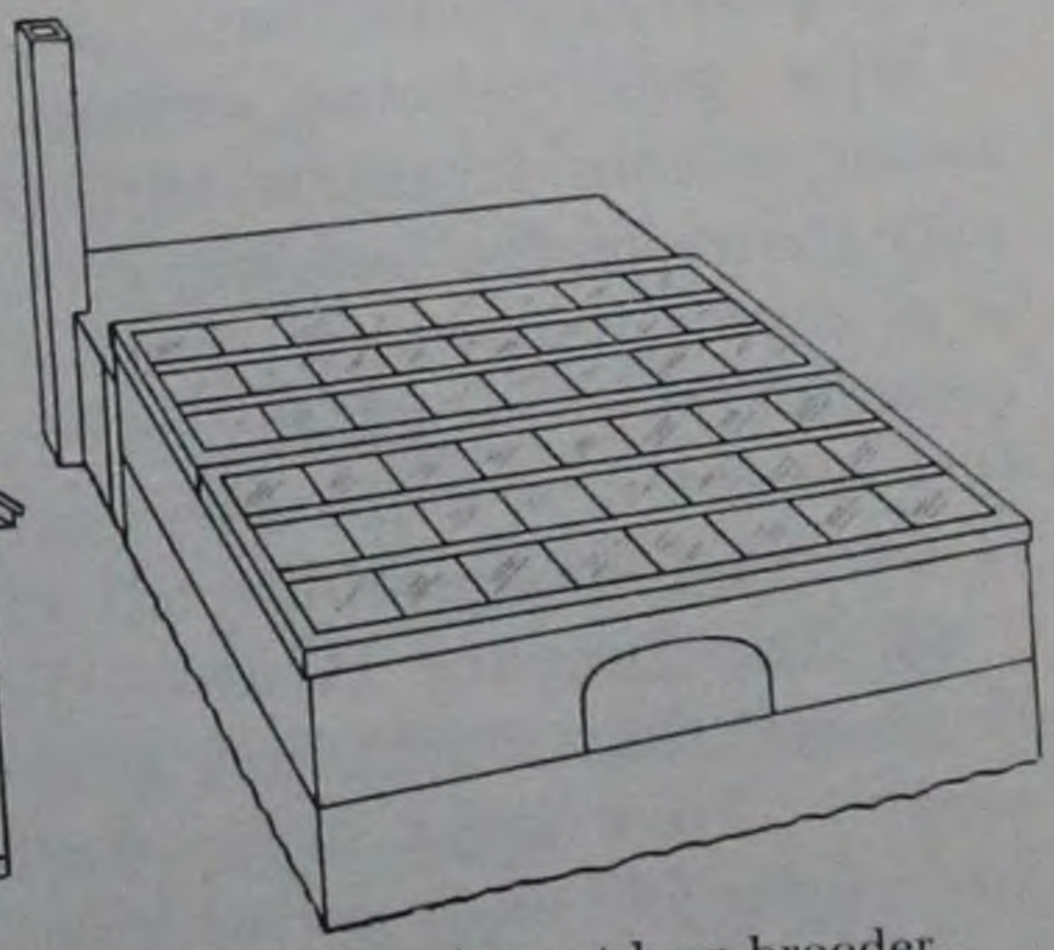


FIG. 39.—An outdoor brooder.

44. Summer-range Shelter.—During the summer season chicks on the range need some protection from heat and from the animals that prey upon them. The summer-range shelter consists of a low building with a roof and wire sides and floor (see Fig. 98). The roof furnishes shade, and the wire floor and sides make the birds safe from predatory animals.

45. Storage of eggs is a problem that should receive attention. By observing certain simple rules, the poultryman is able to place high-quality eggs on the market. By advertising this fact he can usually sell at a premium. The eggs should be gathered several times a day and stored in a cool room, where the relative humidity is high. The low temperature prevents deterioration, and the high relative humidity decreases evaporation losses through the shell, thereby avoiding shrinkage of the egg. A small

cave designed to hold two cases, shown in Fig. 41, was built and tested. A 2-in. sand floor was moistened each morning. The ventilation system provided caused evaporation of water and con-

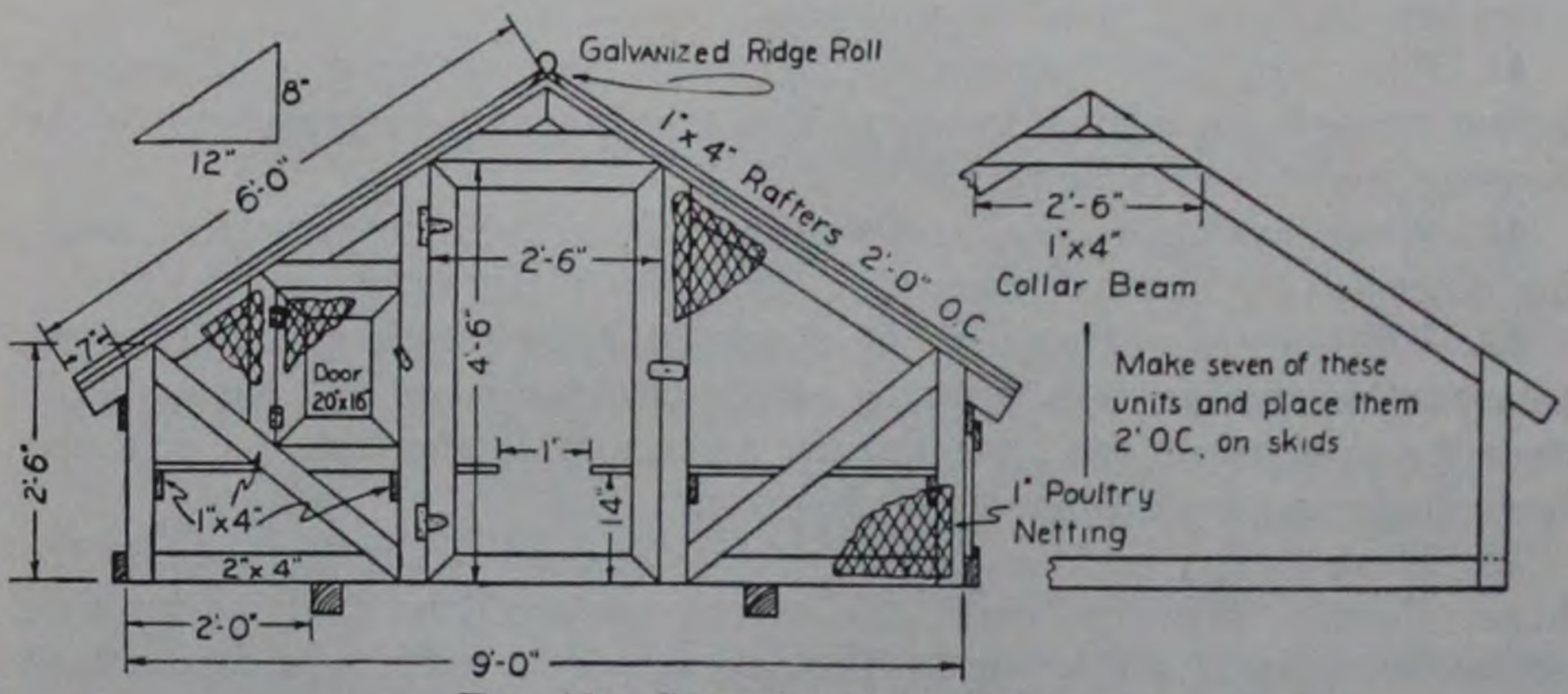


FIG. 40.—Summer-range shelter.

sequent cooling of the interior of the cave. A cave or cellar or refrigerating unit may be used for egg storage if the conditions for temperature and humidity can be maintained.

FIG. 41.—Two-case egg cooler.

The special egg-storage cave can be built near the poultry house, where it will be convenient.

Questions and Problems

40. Explain the reasoning back of the statement that "a farm poultry flock should be either 50 or 500 or more hens." What are the items that enter into the cost of poultry products?

41. What are the requirements that must be considered in planning a laying house? In what ways can these requirements be compared to the housing requirements for people?

42. What conclusions can be drawn from the experimental work on housing described in the text in regard to humidity? Temperature?

43. What is the purpose of the straw loft? A caretaker at a barn expressed the opinion that bringing straw into the barn and scattering it over the floor made the barn warmer and more comfortable. Could this have made any such difference? Explain.

44. Most poultry houses are designed for the caretaker rather than for the hens. Is this statement true? What changes could be made to improve the environment for the hens? The average cow produces 34 Btu of heat for each square foot of wall in her share of the enclosing structure. How would a hen compare to this in the average poultry house?

45. Is a poultryman justified in investing more than the minimum of $1 per bird for a poultry house?

46. What per cent of the annual cost of the poultry enterprise can be charged to housing? What per cent to feed? What is the average annual cost per bird for housing? A 50 per cent increase in the annual cost for housing would be equivalent to what percentage increase if applied to feed?

47. What criticism might be offered of the present design of brooder houses?

48. What improvements are needed in the care of eggs in Missouri in order to improve their salability? How may such improvements be accomplished on the average farm?

CHAPTER XI

BUILDINGS FOR THE HOG ENTERPRISE

Hog raising has been one of the most profitable of the animal enterprises on corn-belt farms. The hog has been called the "mortgage lifter," and in many cases has been rightfully named as such. This enterprise has furnished a means of utilizing the vast corn crops of the Middle West in a manner that has been convenient and profitable. The market in former years discriminated little against size of hogs and would accept fat hogs at a premium. The farmer could carry his hogs along on a maintenance ration and then feed them out when corn was available and the market suited him. Conditions influencing the enterprise, however, have changed materially in recent years, and the present-day producer is confronted with problems that did not exist in earlier times. One of the most important of these is the change in type of hogs desired.

Because of the introduction of vegetable oils for cooking, the market for the lard hog has been materially decreased. The efficiency of each hog producer has been increased in later years by the adoption of better practices, thereby making possible the production of a greater number of hogs. The combination of all these conditions makes it essential that every phase of production be considered if profits are to be realized.

The increase in animal population on farms has introduced problems of sanitation. When hogs could be given a wide range there was not so much trouble from parasites and disease, but when large numbers of hogs are kept on a restricted area throughout the year it becomes necessary that strict rules of sanitation be observed in order to avoid trouble and loss.

46. Methods of management of the hog enterprise may profitably be reviewed as a preliminary to the study of housing requirements. There are four rather distinct methods of managing the hog enterprise. The method used in former years is still being followed on some farms. On these farms there are central hog

houses connected to permanent yards and pastures. In many cases the poorest part of the farm adjacent to the building group was fenced hog-tight and used as a hog pasture year after year.

Many farmers having this kind of setup have improved upon it by rotating their hog pasture from year to year. If pigs are farrowed in winter the central house is thoroughly cleaned and the pigs kept in the house until such time as they can be moved to clean pasture. In most cases the sow and pigs are hauled to their new location to prevent their becoming infected by crossing yards or the previous year's pasture. Individual houses are used for shelter in the new pasture.

A few farmers are having considerable success with a plan of management known as the *confinement system.* The central house and adjacent concrete-floored yards are thoroughly cleaned. Pigs are farrowed, and the sows are left in the house with the pigs until weaning time. The sows are then removed, and the pigs are confined in these quarters until ready to market. The house and the adjacent concrete-floored yards are cleaned at least once a day and scrubbed at least twice a week.

Still another plan, known as the *McLean county system,* requires an individual house for each sow, and the house and sow are moved to the pasture field before farrowing time. The sow and pigs are kept here until the pigs have passed the period when they are subject to infection and then placed in the regular yards for feeding.

47. Objectives in Planning Buildings for the Hog Enterprise. After the system of management has been selected the buildings can be planned best to meet the needs. The main objectives in planning buildings for the enterprise are comfortable conditions for the hogs, convenience for the operator, and a housing cost that will be in keeping with the income from the enterprise.

The exact limits of comfort for hogs are not well defined, but general practice in the industry has established some useful information. It seems that the limits of temperature, humidity, and air movement are about the same as for poultry—that is, in winter a minimum of 32°F. in still air, to a maximum of 85°F. in summer, with no limitation on air movement. It is true that hogs will not be exactly comfortable at or near these extremes, but experience has shown that growth will not be seriously retarded or health impaired by these conditions. Relative

humidity of 50 or 60 per cent is desirable, with an allowable variation above and below this of from 10 to 15 per cent. Floors that are not affected by capillary moisture from below, built of material that can be washed at intervals, are essential for comfort and sanitation. The control of humidity by changing the air in the building takes care of the problem of air purity in most cases.

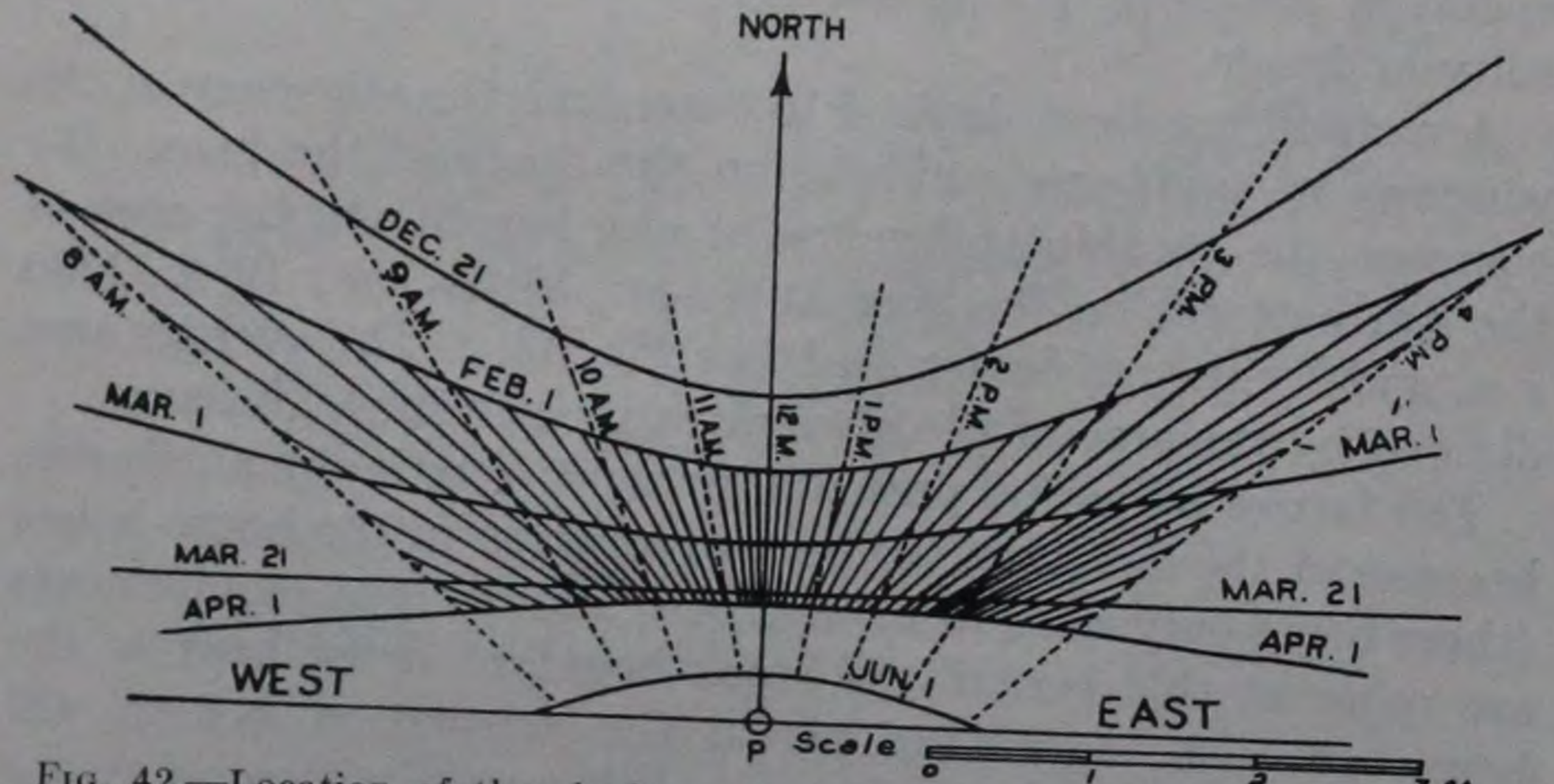


FIG. 42.—Location of the shadow of a point at different dates and hours. This diagram will be useful in determining the proper height of windows, or in developing sun patterns for houses already constructed. The curves are drawn for a latitude of 37 deg. To secure similar sun patterns, windows would need to be lowered or raised one foot for each 6 deg. of movement north or south. To locate the corners of a window pattern on the floor, the horizontal angle of the sun's rays can be found from this chart by use of a protractor. The diagram gives the length of shadow for 1 ft. of height based on the scale shown. Find the length of the shadow, using scale, and multiply by the height of the window to determine the actual location.

To locate the shadow of a point at any date and time of day, measure the angle the sun's rays make with the meridian and the distance from the point *P* to the shadow. In making sun patterns on hog-house floors, locate the four corners of the windows.

In hog-house designs in past years many sacrifices have been made in order to admit sunlight to the building. Many designs allow 4 sq. ft. of glass per pen, and the windows have often been placed near the ceiling or in the roof, where the heat loss is greatest. Such windows, unless they are covered with shutters at night, will be the cause of low temperatures, and the benefits secured from the relatively few hours of sunshine each day in winter may be offset by uncomfortable conditions during the remainder of winter days and nights. In summer there is not much need for direct sunshine in the house; in fact, the house will

probably be more comfortable if sunshine is excluded. Here the shutters could be used again to advantage. The sunshine deficiency for the winter period might be made up in the feed or by a special sun pen provided to enable the pigs to get the sunshine needed without interfering with other objectives in design. Adequate lighting, natural or artificial, must be provided for the operator, but his requirements will not be enough to cause difficulty in design.

A method has been devised to determine the efficiency of the windows in supplying sunshine on the floors of the pens. To compute the sunshine efficiency of any hog house, the area of the sun patterns on the floor at 9 A.M., 10:30 A.M., 12 M., 1:30 P.M. and 3 P.M. was determined (see Fig. 42). The average area divided by the area of the glass gives the sunshine efficiency.

The farrowing period presents the most exacting requirements because of the fact that the heat production in the house is less (there being only one sow in each pen) and the heat requirements are more at this period. If stock hogs are to be kept in the house after the farrowing period the ventilation system will need to be made large enough to meet the needs, with some means of reducing the rate of air change for the farrowing period.

Convenience for the operator can be included in the design to best advantage by giving consideration to the different chore operations to be carried out. The operations requiring the most time and energy should be given the most important place in the planning. Cleaning is one of the important chores. If the enterprise is large enough so that a load of manure is salvaged with each cleaning, it may be advisable to provide a central service alley wide enough to drive through with a wagon or spreader. However, the tendency to provide a higher degree of sanitation requires cleaning several times each day. A narrow service alley and a pneumatic-tired cart or overhead carrier may be found to be more practical under these conditions. By using the proper kind of equipment, most of the work of cleaning can be done from the central hall. A 7-ft. 6 in. or an 8-ft. ceiling is used in the center of the building; but side pens may be constructed with lower side walls and ceilings, resulting in a reduction of exposed-wall area, a saving in available heat, and consequently in more comfortable conditions at farrowing time. In addition to making the building more comfortable, the mainte-

nance of temperatures above freezing will reduce the work of cleaning the floors. Proper design for drainage when floors are washed is also important.

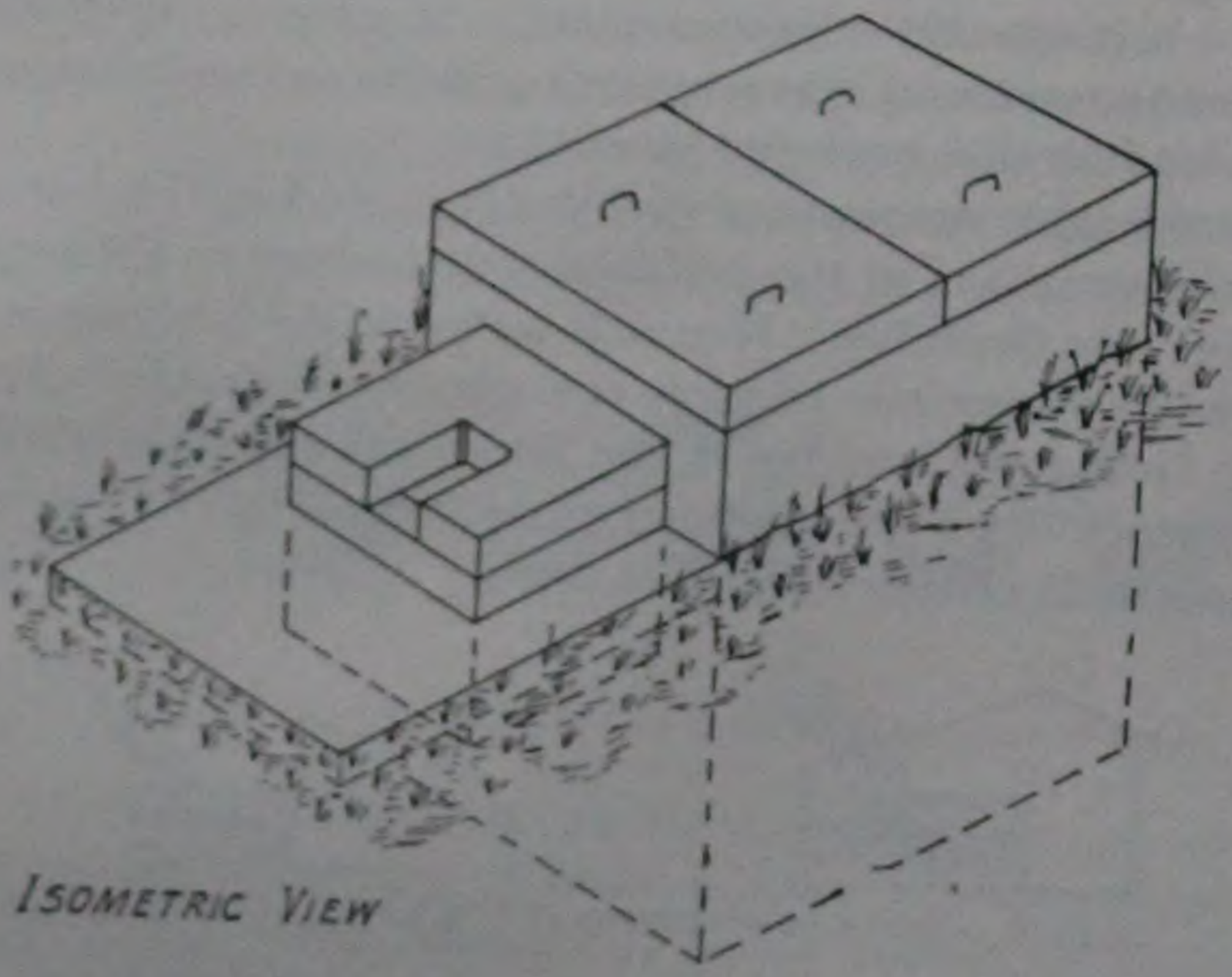


FIG. 43.—Automatic hog waterer.

Feeding is an important item in chores connected with the enterprise. Storage space for the different feeds needed and a room in which they may be processed should be provided. The processing may consist of grinding, mixing, cooking, or soaking. Whatever it may be, it will be worth while to consider space for

and convenient arrangement of bins and equipment. Feed must be ground in comparatively small quantities to prevent spoiling. Soaking grain or making up slop feeds must of necessity be a frequently repeated chore. If water is piped into the processing room and bins and mixing tanks are made convenient, much undesirable work can be avoided.

Considerable amounts of bedding are used in this enterprise, and storage space in the building or immediately adjacent to it will be very desirable. Running water in the building is essential, and connections to each pen may be desirable. An automatic frost-proof waterer in the house will be especially helpful when stock hogs are confined there. See Fig. 101 for such a waterer built of concrete.

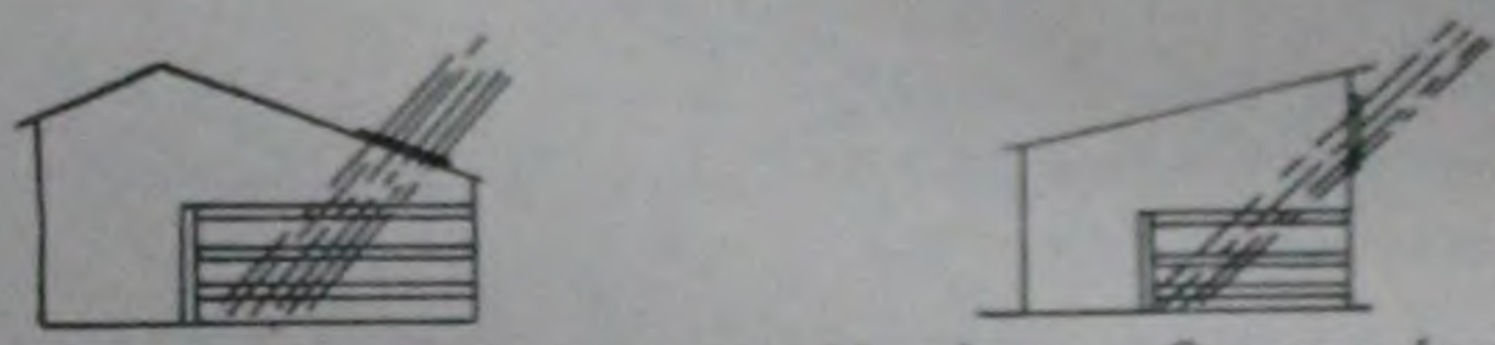


FIG. 44.—East and west types of hog house. One row of pens.

Pen partitions and gates should be planned to be convenient for handling the sows and pigs. Partitions should be removable to serve best when the house is needed for stock hogs.

Cost.—If a house were built to meet the requirements of the enterprise and if good methods were used, it seems that $75 per pen would not place too great an annual charge against the enterprise. Assuming that the structure would serve over a period of 40 years, the annual cost per pen would not exceed $4 per year, upkeep, interest, and amortization included. This would make a charge of 25 cts. per hog if two litters of eight were raised each year.

48. Types of Centralized Houses.—These may be divided into two general classes based on orientation: the east and west and the north and south types. Some farmers prefer a single-row arrangement of pens. Two common types of single-row houses are shown in Fig. 44.

Where two rows of pens are desired and where the east and west type of house is used, the three designs shown in Fig. 45 are often used. Figure 45*a* is called the *semimonitor house*. This type is better for the Northern part of the United States, because the upper row of windows need not be placed so high

to secure sunlight in pens as is the case farther south. The principal objection to this type of house is the excessive loss of heat through the windows. Heated air from the hogs rises to the top of the building and is dissipated through the glass. The comparatively small amount of heat available is soon lost, and temperatures necessary for comfort are difficult to maintain. The house shown in Fig. 45*b* can be made lower than the semi-monitor type and offers some improvement in heat conservation.

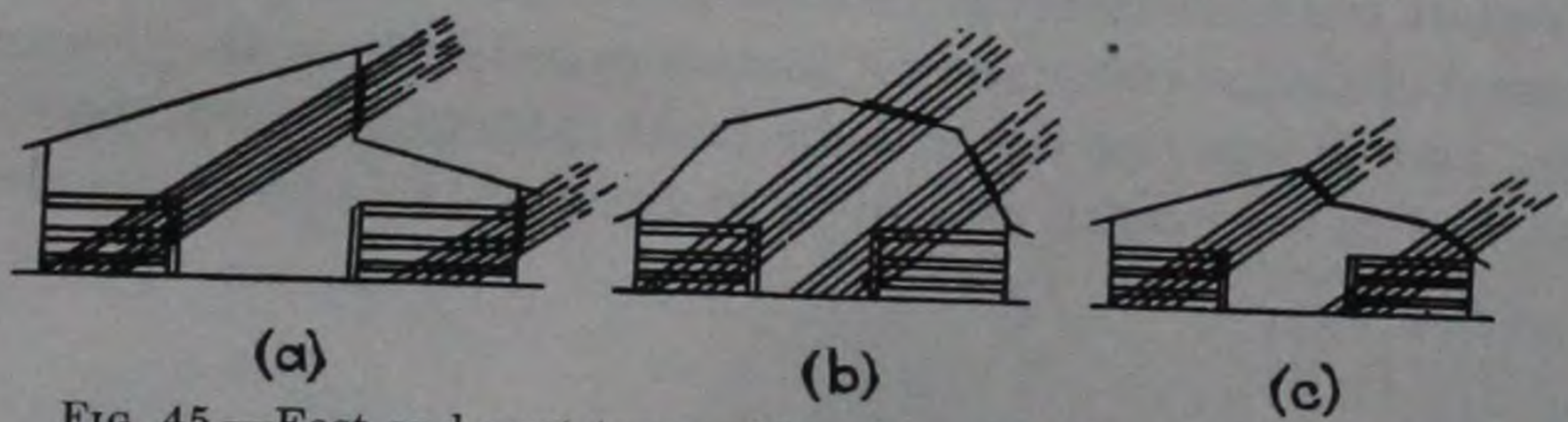


FIG. 45.—East and west types of hog houses. Two rows of pens.

Figure 45*c* shows a house in which the maximum use of the glass is made, permitting slightly smaller windows than are necessary in the other houses. If inside covers are provided for the windows, heat losses may be controlled, provided the remainder of the structure is well insulated.

Three designs of north and south types of houses are shown in Fig. 46. A building developed at Iowa State College is illustrated in Fig. 46*a*. There are some objections to this design

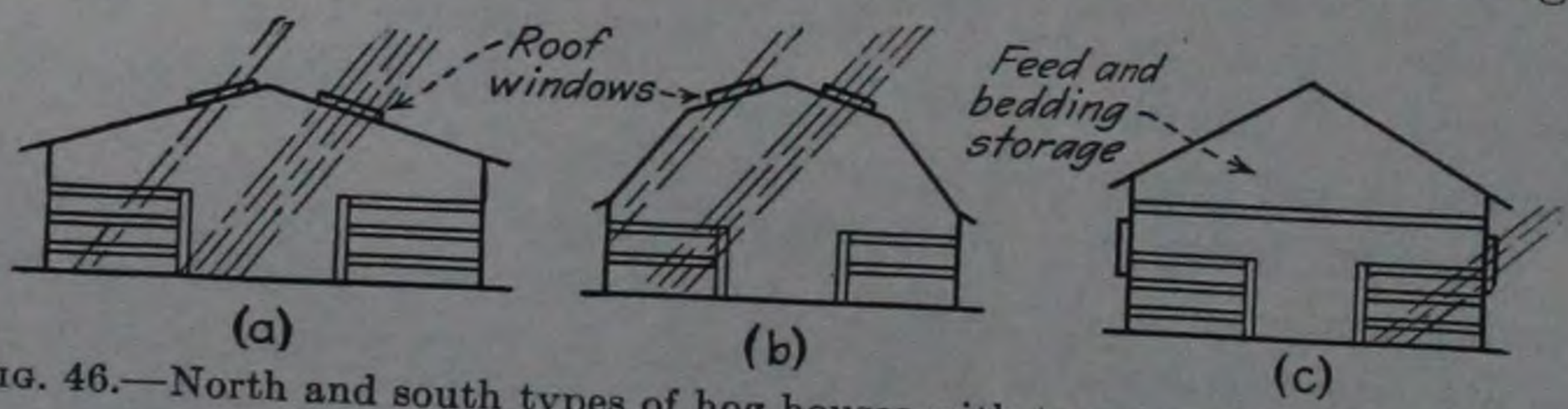


FIG. 46.—North and south types of hog houses with two rows of pens: (*a*) Iowa type; (*b*) gambrel-roof type; (*c*) Nebraska type.

because the windows are placed in the roof where the temperature difference between inside and outside will be the greatest. The windows on the west roof slope are exposed to winter wind, increasing the heat loss at a time when the heat must be conserved for comfort. Another objection is that at certain times during the day half the windows will be radiating heat and will not be admitting sunshine. Figure 46*b* shows a gambrel-roof house that has lower side walls than the building in Fig. 46*a*, and

may be built without inside supports. A hog house developed at the Nebraska Experiment Station is illustrated in Fig. 46*c*. This plan provides a straw loft that has three functions: it furnishes insulation, it may absorb some moisture, and it furnishes a convenient location for a supply of bedding. It does not give as good distribution of sunshine as some other designs but may provide other factors of comfort to better advantage.

Ventilation of the centralized house is difficult because it is often not possible to secure sufficient height for the outtake flue. These buildings are made as low as possible to reduce exposed area, and unless the flue can be built into an adjacent building that has more height, it will be necessary to build it up above

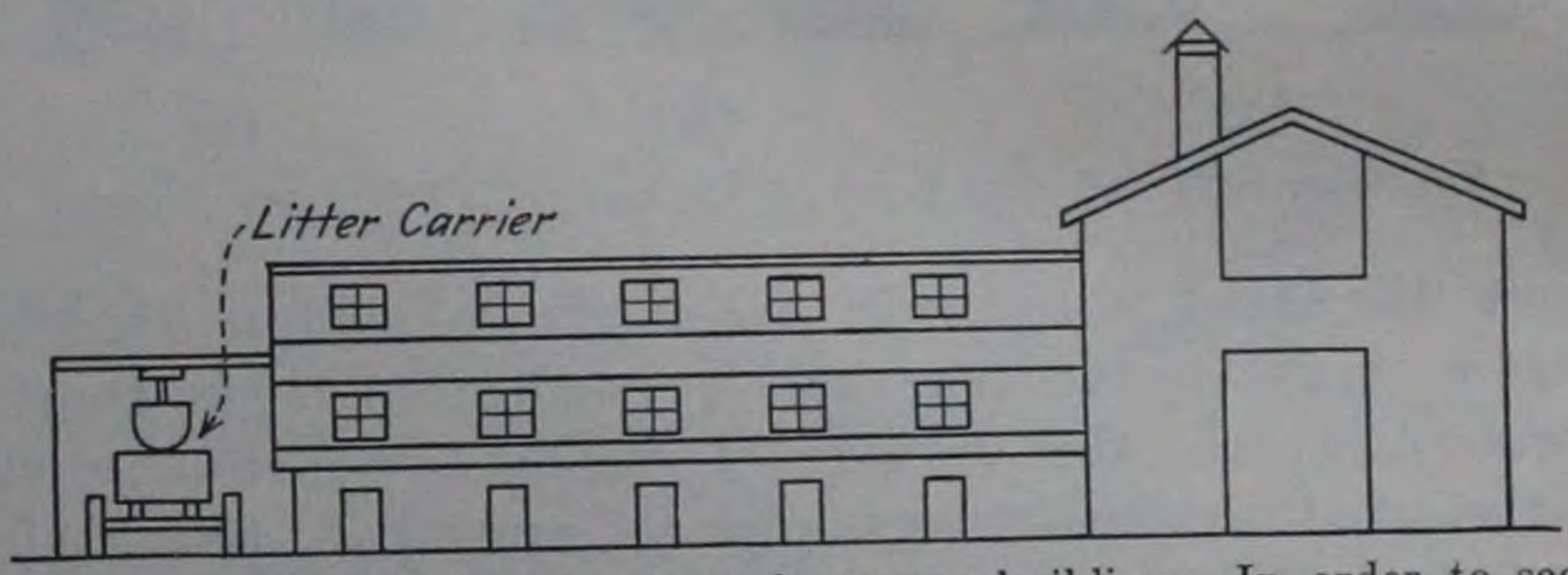


FIG. 47.—Combination hog house and storage building. In order to secure greater height for the ventilation flue, it is located in the storage building.

the structure itself. Figure 47 shows a plan whereby a hog house is built adjacent to a feed and bedding storage building. The outtake flue is in this structure where greater height can be secured. If the flue is well insulated it will function when connected to the hog house at the floor level.

49. The Individual Farrowing House.—The individual farrowing house must be built to meet some very definite requirements; for instance, it must be built so that it can be moved from place to place with ease (they are commonly mounted on skids). It must be built so that it can be opened up and sunned at intervals; it must be so designed that it will be easy to clean; it must be strong; and it must be low in cost. These requirements demand that good nailing and high-quality workmanship and material be used throughout. A certain amount of wracking and twisting accompanies the process of moving, especially over rough ground.

The house illustrated in Fig. 48*a* was developed by farmers in northwest Missouri and is preferred by stockmen in that state.

It furnishes protection for pigs under the long sloping roof. It is comparatively low, limiting the exposure and making temperature control possible. The wall door is on the lower right-hand side of the south end, and the roof door is on the west end of the south sloping roof, thus making it possible for the attendant to clean the house without getting inside. The house shown in Fig. 48*c* has a similar arrangement of doors. Figure 48*b* illustrates a house that has a door section on the west roof to aid in the cleaning process. Ventilation is secured through a small opening in each gable.

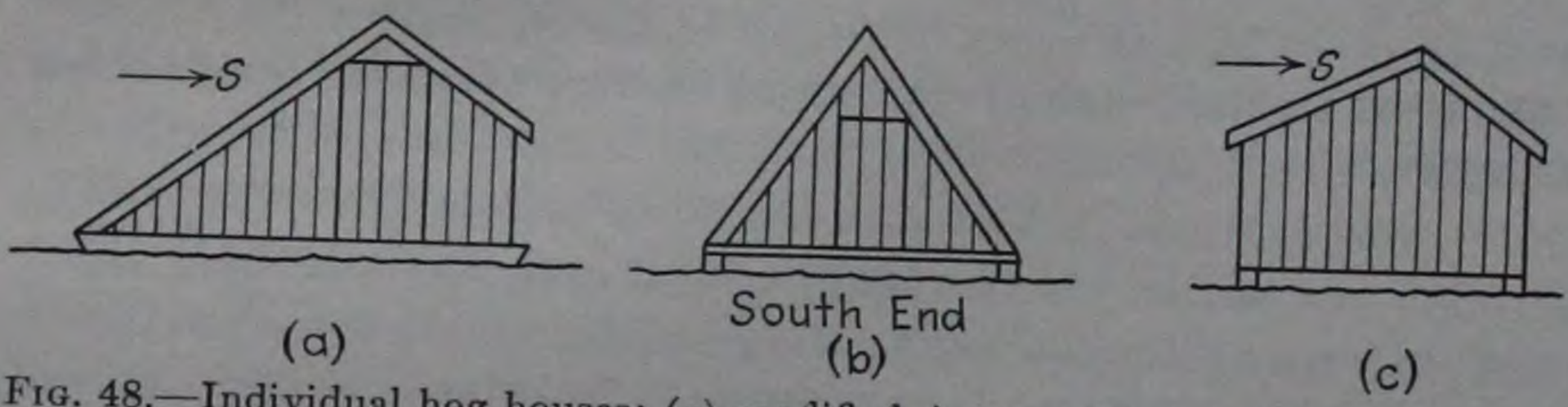


FIG. 48.—Individual hog houses: (*a*) modified A type; (*b*) A type; (*c*) combination roof.

50. Chore Equipment.—The chore labor is greatly increased with the use of individual hog houses. Water, slop, feed, and bedding must be supplied at each house at least once a day if best care is given. Some farmers use a "chore wagon" to aid in this work. A wagon is equipped with a water tank having a hose connected to fill individual waterers, a swill barrel, and feed and bedding space. One trip completes the chores with a minimum of time and labor. An automatic waterer attached to a barrel makes a very good system of watering under these conditions. The barrel can be filled and water is then available as needed. A special individual waterer of this type equipped with a lamp to keep it from freezing has been placed on the market and is a valuable piece of equipment for the winter period.

Questions and Problems

49. The hog has been called the "mortgage lifter." Explain this statement. Will this probably be true in the future if development of vegetable oils increases?

50. Discuss the various methods used in managing the hog enterprise, explaining the essential features of each.

51. What are the general requirements of a good environment for hogs? Why are these requirements different today than in former years?

52. There is a general belief that a great many hog houses are uncomfortable during 90 per cent of the year in order to get a few hours of sunshine in the pens at farrowing time. Is this true? Explain.

53. A good central farrowing house should have everything that will be needed in taking care of the hogs. What will this include? Is it practical to meet these requirements?

54. Give the good and bad qualities of different types of hog houses as to orientation, heat loss, ventilation, and convenience for the caretaker.

55. Describe what you consider to be a good ventilation system for a central hog house.

56. What are the principal difficulties encountered in using the individual-house system at farrowing time? Why has this system been adopted by such a large number of farmers? Describe equipment and practices that will decrease chore time where individual houses are used.

57. What are the building requirements for the confinement system of hog production?

CHAPTER XII

BEEF CATTLE AND SHEEP

THE BEEF-CATTLE ENTERPRISE

A farm is classified as a beef-cattle farm when the major part of the income is derived from beef cattle. This enterprise may require a large investment if it consists of a herd of beef cows kept for the production of calves to be sold as breeding stock or fed out as baby beef each year. It will require a minimum investment in buildings if the enterprise consists of the purchase of steers in early spring to be fed and sold in the late fall.

51. Environment for Beef Cows.—Beef cattle are not so sensitive to low temperatures and air movement as are the dairy breeds. Some control of temperature, humidity, and air movement is required, however, in the stable in which beef cattle are housed. Diseases that are encouraged by poor housing must be guarded against fully as much as in the dairy herd. Good construction, insulation, and ventilation are all essential in maintaining the comfortable conditions needed for this enterprise.

Tie stalls, large enough so that the calves may be tied beside their dams, are often used, especially where the increase in the herd is sold for breeding purposes. Gates are often built at the rear of the stall partitions so that each stall can be made into a box stall at will. Some farmers prefer the face-out type of arrangement, because they believe it shows off the herd to better advantage (see Fig. 49). Stock can be backed out into the central hall for inspection; summer ventilation is more easily secured; cleaning may be accomplished more easily, since this work is all confined to the one alley. Time for feeding, however, will probably be increased by this arrangement. Wood or clay floors are preferred, although concrete is recommended for service alleys. Adequate lighting, either natural or artificial, is essential. If the barn is to be a complete unit, storage space for one season's supply of feed and bedding should be provided and plans made for handling this feed at harvest and in the daily feeding process in as convenient a manner as possible.

The cost of such a beef-cattle barn need not be quite so great as for a barn to house an equal number of dairy animals; the actual amount that should be expended will depend on the value of the cattle being produced and the consequent annual income.

Housing for feeder cattle presents fewer problems than for any other animal enterprise on the farm. Feeder cattle are fed as much feed as they can consume economically. The assimilation of this feed and the body covering built up as a result enable these animals to withstand exposure much better than those on a maintenance ration or those using the feed for other purposes, such as for the production of milk. A reasonable amount of exposure to the weather may sharpen the appetite of beef animals, thereby causing them to eat more and consequently to make greater gains. Several years ago an experiment was conducted at the University of Missouri to determine the housing needs for feeder cattle. The test cattle, two-year-old steers, were divided into three lots. The first lot was placed in a barbed-wire enclosure for the winter; the second lot was given access to an open shed; and the third lot was housed in a warm barn. The first group made the most gain, the second group the most economical gain, and the third lagged behind in both the amount and economy of gain. In addition to the benefits derived from the open shed, saving of time in getting the stock safely housed when unusual storms occur is also worthy of consideration. One farmer in northwest Missouri reported that his cattle barn had paid for itself before it was completed. A 3-day storm came on with very little warning. The cattle caught in the field were lost, whereas all those that reached the barn came through in good shape.

52. Barns for Beef Cows.—Figure 49 illustrates a barn that is designed to hold all the hay that will be needed to feed the cows and calves housed for one season. The hay is stored overhead, and the ground floor, with the exception of a small space for grain, is devoted to stalls and service alleys. The feed grinder is to be placed in the central alley and the tractor belted to it through the door. Ground-feed bins, a mixing floor, and a mixed-feed bin are located on the second floor. The manure spreader or a wagon can be driven through the barn to facilitate cleaning. Hay chutes can be located as desired, because the problem of dust created by throwing down hay will not be serious

in this barn. A single-stack ventilation flue is located near the grain bins and extends up to a ventilator head located near one end of the barn at the ridge. A mow ventilator head is placed at the opposite end of the barn to balance the design.

Figure 50 shows a barn design in which the entire center section from the ground to the roof is used for the storage of hay. Stalls and pens are placed in sheds on each side of the central hay-storage space. The sheds are provided with a straw loft

FIG. 49.—Barn for beef cows and calves. Two floor plans.

made of poles or strips, with at least 12 in. of straw covering. This allows some air circulation and prevents drafts that are sure to develop in a barn of this type if some provision is not made to control air movement. This plan lacks some of the advantages found in the barn shown in Fig. 49. The work of cleaning it cannot be done so conveniently, and the herd is divided and may not show off to such good advantage.

If the main supply of feed is stored in a central supply building or stacked in the field, a barn with space for a limited supply of feed and bedding is sometimes used. Figure 51 shows a barn that holds about a 2-week supply of feed and bedding for the

animals housed. This plan of management may save time in the harvest season, but it requires more time for hauling feed in the winter.

Where cows and calves are on pasture it is the usual practice to give the calves some extra feed. Figure 52 shows a self-feeder and pen arranged with gates that permit calves to enter but that exclude cows.

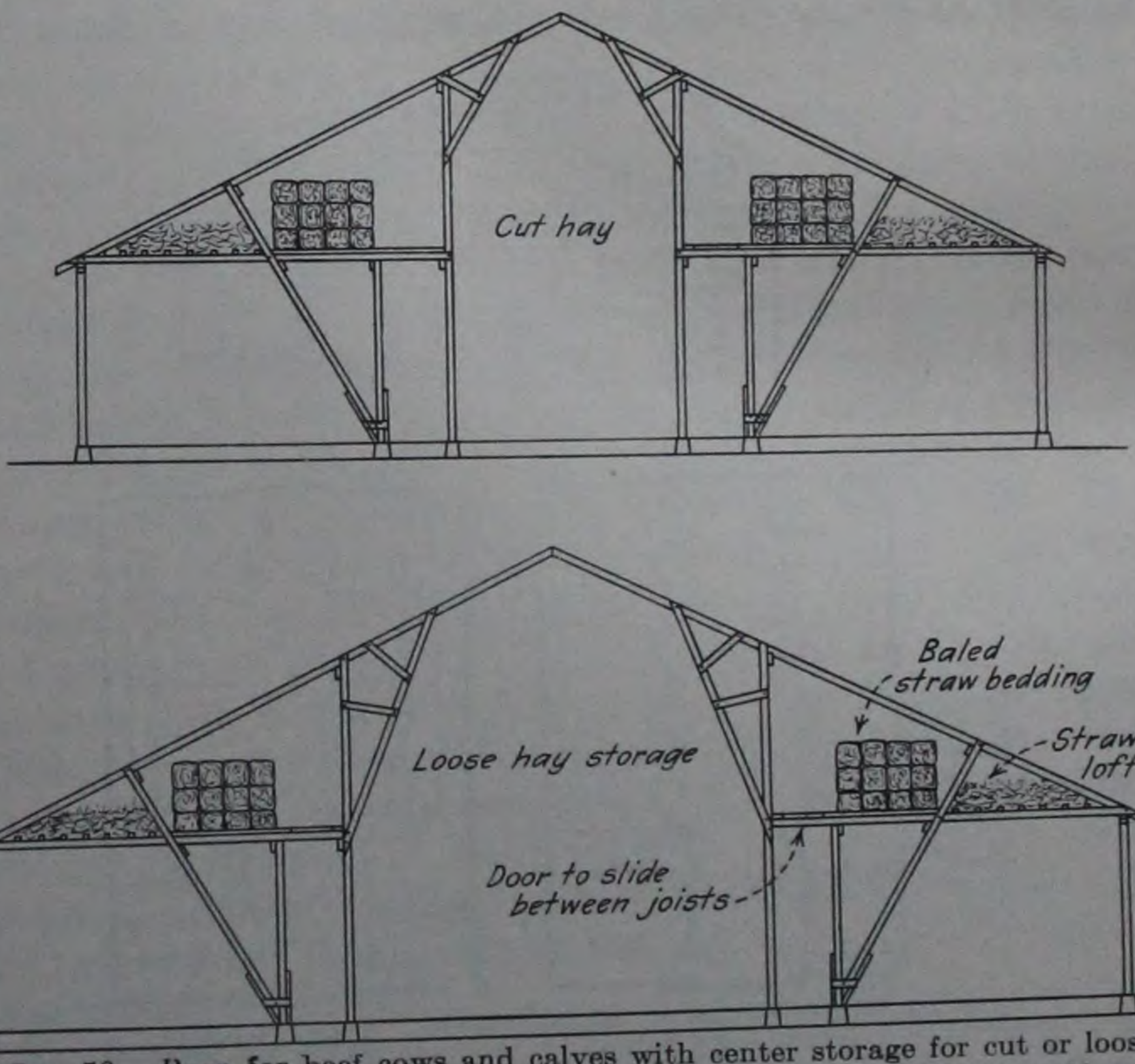


FIG. 50.—Barn for beef cows and calves with center storage for cut or loose hay. The two barns have the same capacity for livestock and for cut and loose hay, respectively.

In designing sheds for beef cattle it is customary to allow from 24 to 36 in. of manger space per animal and from 28 to 42 sq. ft. of floor space, depending on the size of the animals. In closed barns 2 sq. ft. of glass per animal is sufficient for the convenience of the caretaker and the comfort of the animals.

Housing for Feeder Cattle.—The Missouri experiment described earlier in this chapter showed that the open shed is probably the best type of building for this enterprise. This shed should open

to the south, and the other sides should be made tight to prevent drafts.

Figure 53 shows a plan that was worked out to meet the needs of a cattle feeder in central Missouri. On this farm the hay was

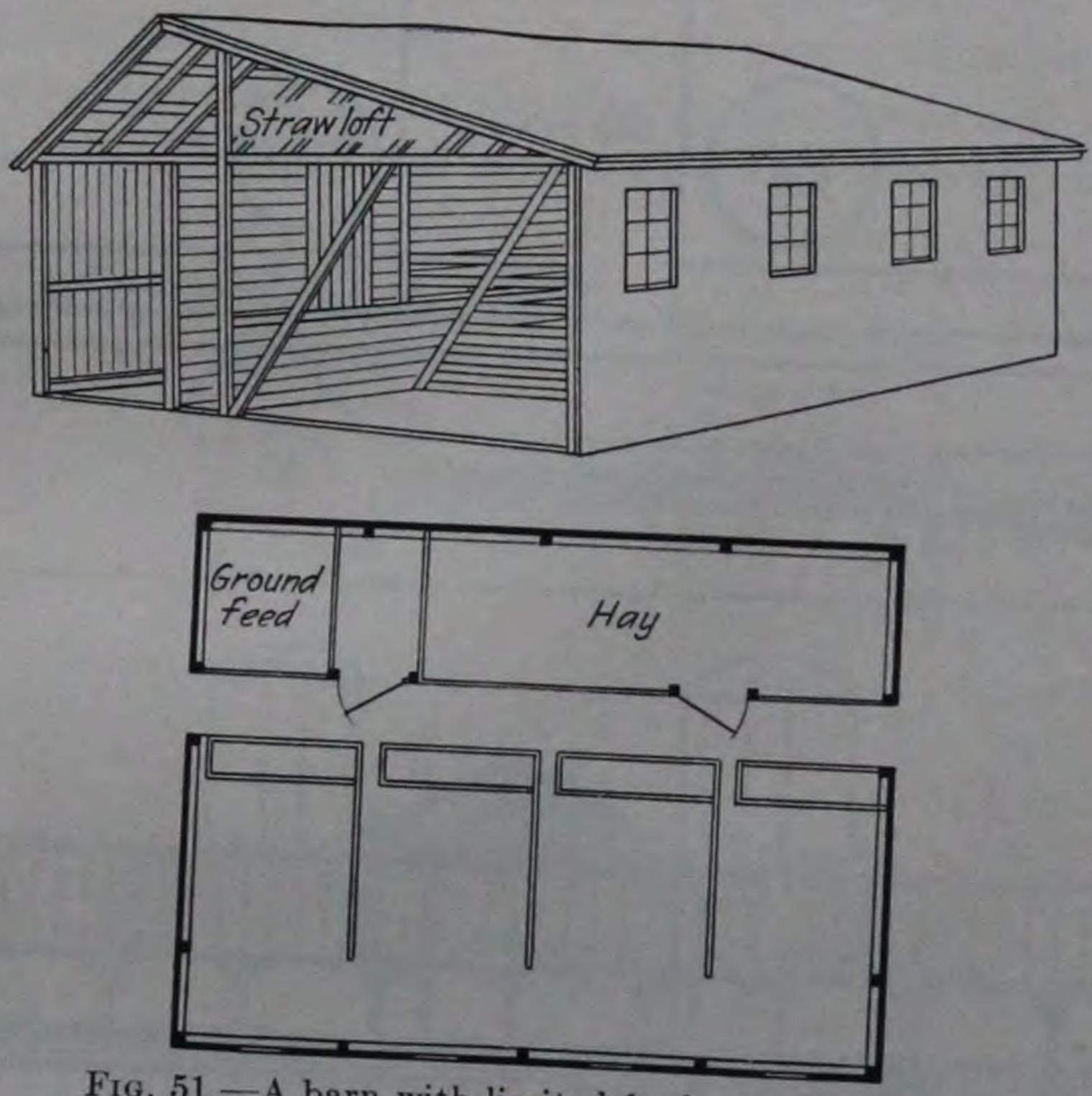


FIG. 51.—A barn with limited feed-storage space.

baled in the field, and the hay-storage structure was made smaller than would be practical if the ordinary method of hay management had been used. The hay-and-corn-storage space

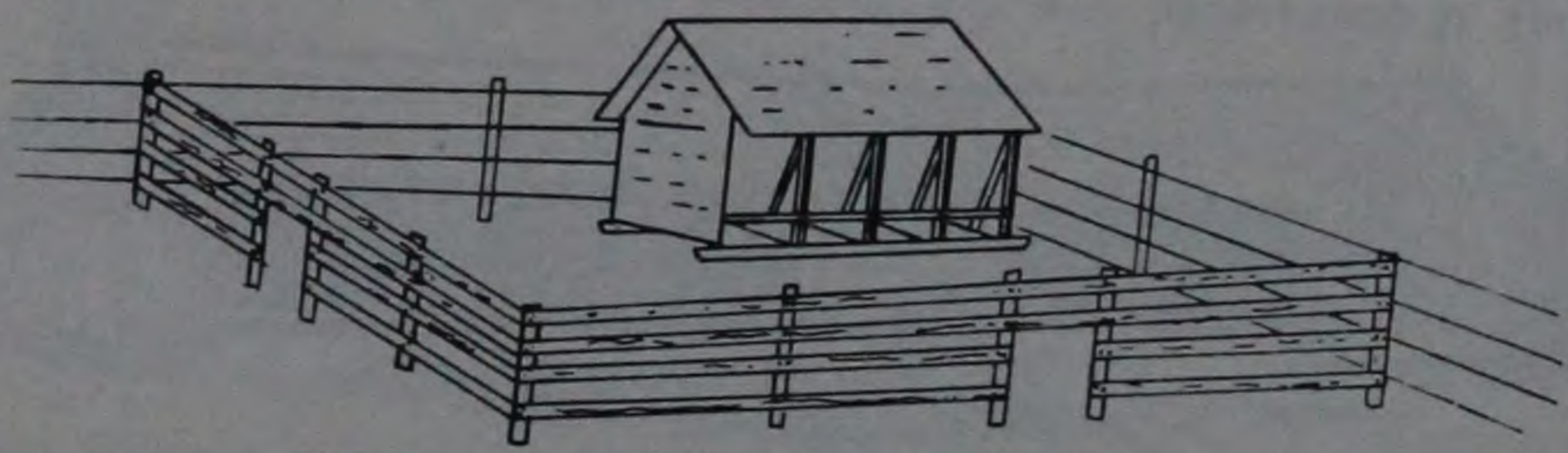


FIG. 52.—Creep feeding equipment for calves.

and the silos were placed at the center of the building to facilitate the feeding operations. Sheds opening to the south are considered ideal for cattle on feed in this climate. Watering

troughs should be placed inside the sheds if possible, since they will be easier to take care of in the cold season, and the stock can drink without being exposed to the winter winds.

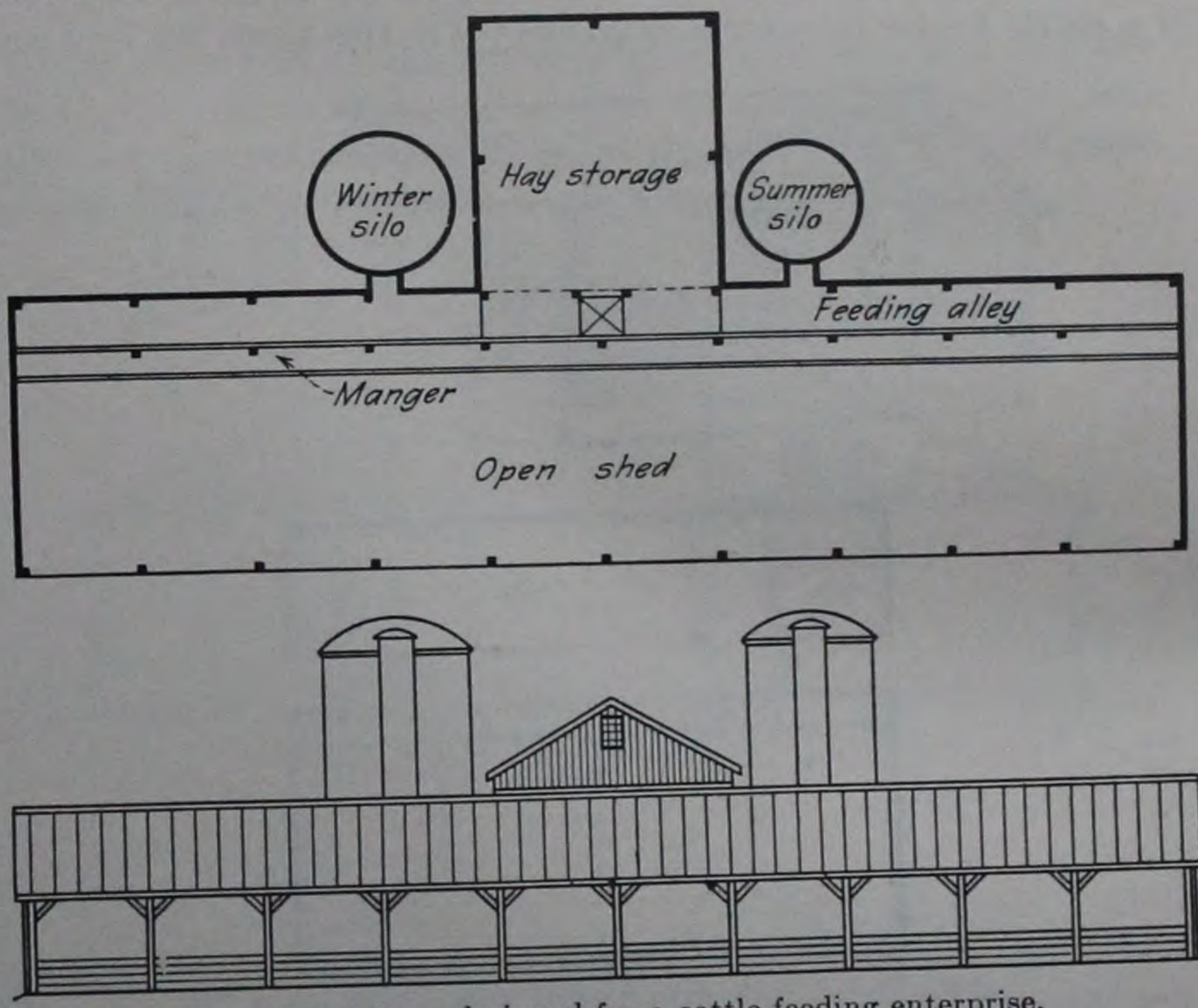


FIG. 53.—A barn designed for a cattle-feeding enterprise.

On many farms a building is provided in the pasture field to furnish shade in summer and perhaps some protection for livestock in winter. Roughage is stacked in the yard near the shed, and concentrates are fed in open troughs. Figure 54 shows

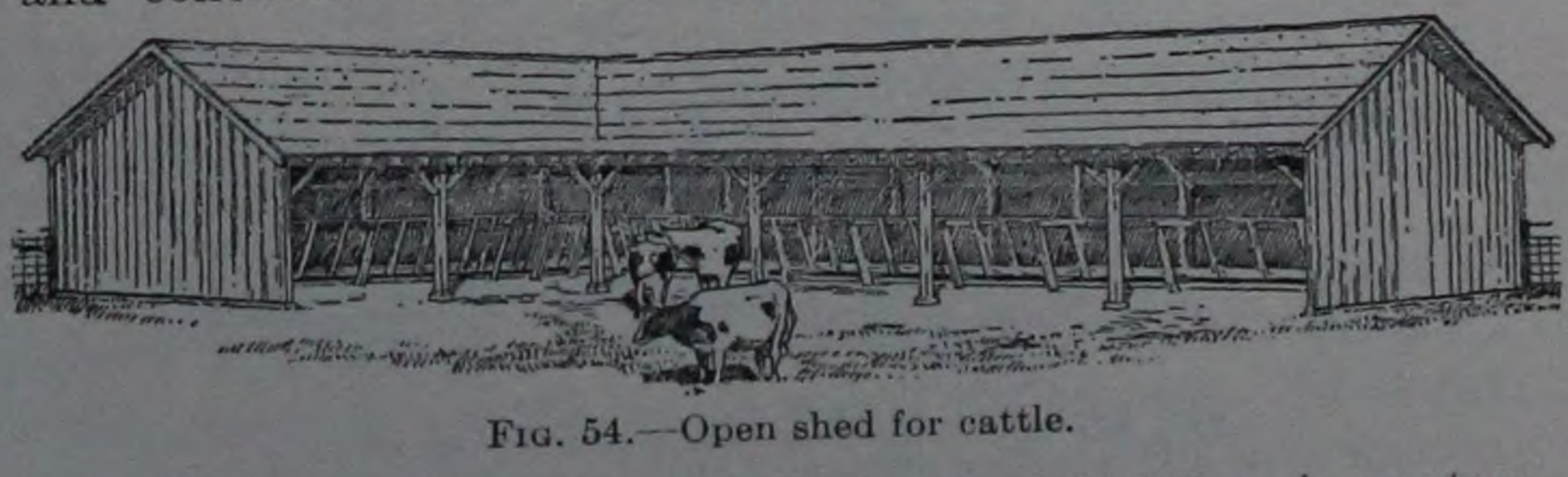
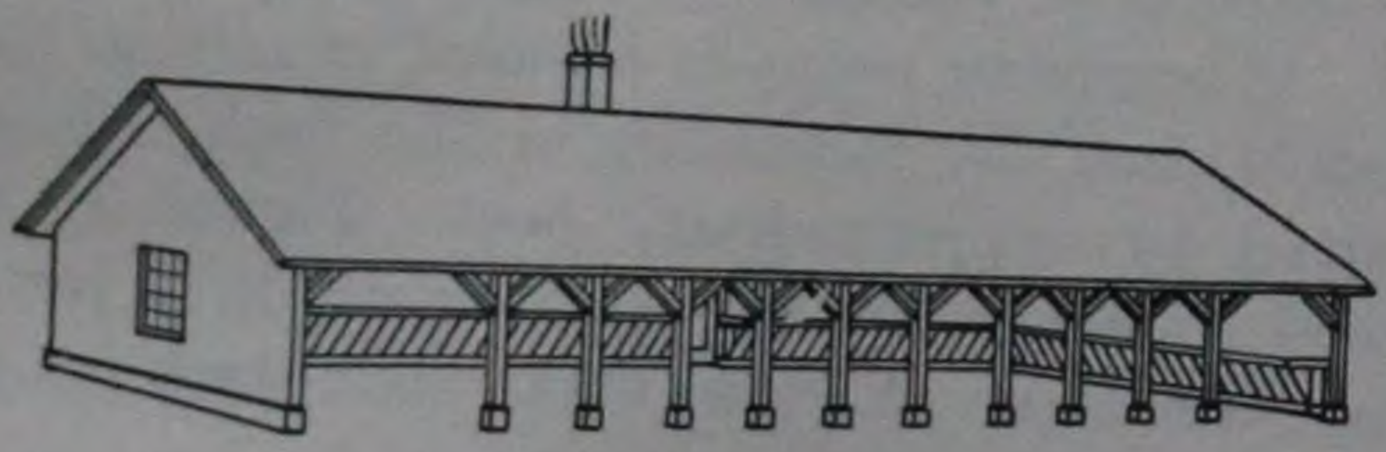


FIG. 54.—Open shed for cattle.

such an open shed. When this type of building is contemplated, thought should be given to feed storage and feeding problems. This shed furnishes only a part of the housing requirements for the enterprise.

THE SHEEP ENTERPRISE

53. Sheep Barns.—The building equipment for sheep raising will depend on the climate, the extent of the enterprise, and the time of the lambing season. In fairly warm climates, where ewes are bred to lamb late in the season, open sheds may be sufficient to bring the flock through successfully (see Fig. 55). If



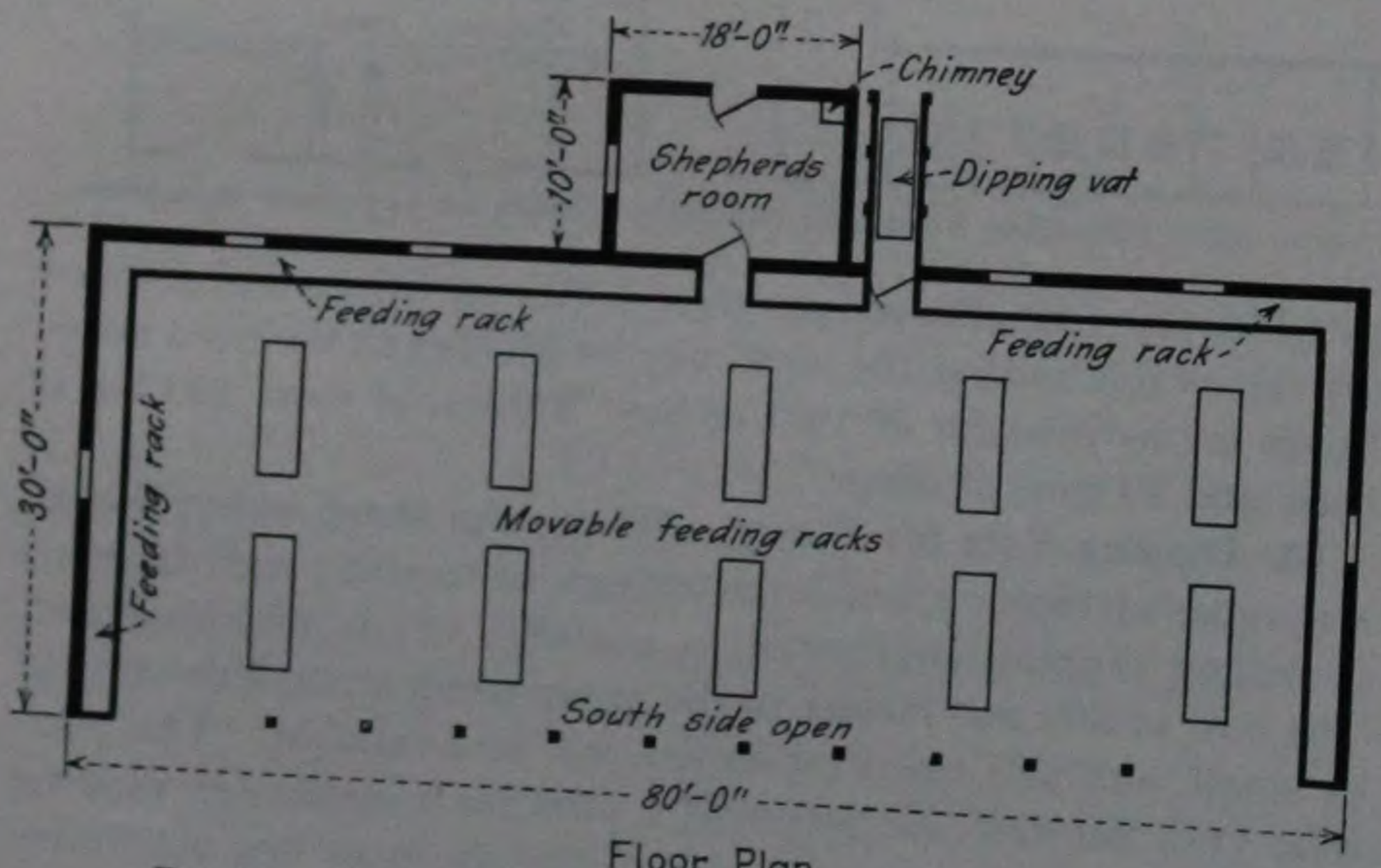


FIG. 55.—Open shed for sheep, with warming room attached.

early lambs are planned for, a lambing shed or warming room, at least, will be necessary. If sheep are given shelter from rain and sleet and provided with dry floors they can withstand cold without damage. Good drainage for yards and pens is essential. A south slope is desirable for winter conditions, although shade and protection from heat in summer are essential. Wood strips

or wire nailed on the underside of the rafters and the space between packed with straw furnishes insulation that will promote comfortable conditions in both summer and winter. Sheep barns should be located so that they can be reached easily because of the early and late chores connected with this enterprise.

On farms located in cold climates, where the raising of sheep is an important enterprise, a closed barn is advisable. An adequate system of ventilation is essential to keep the air dry and fresh. A warming room to be used in getting lambs started is advisable, but the remainder of the flock will usually not be benefited by supplementary heat. Figure 56 shows a barn planned to house the sheep enterprise in a section where the climate is severe. A New York single-stack ventilation system

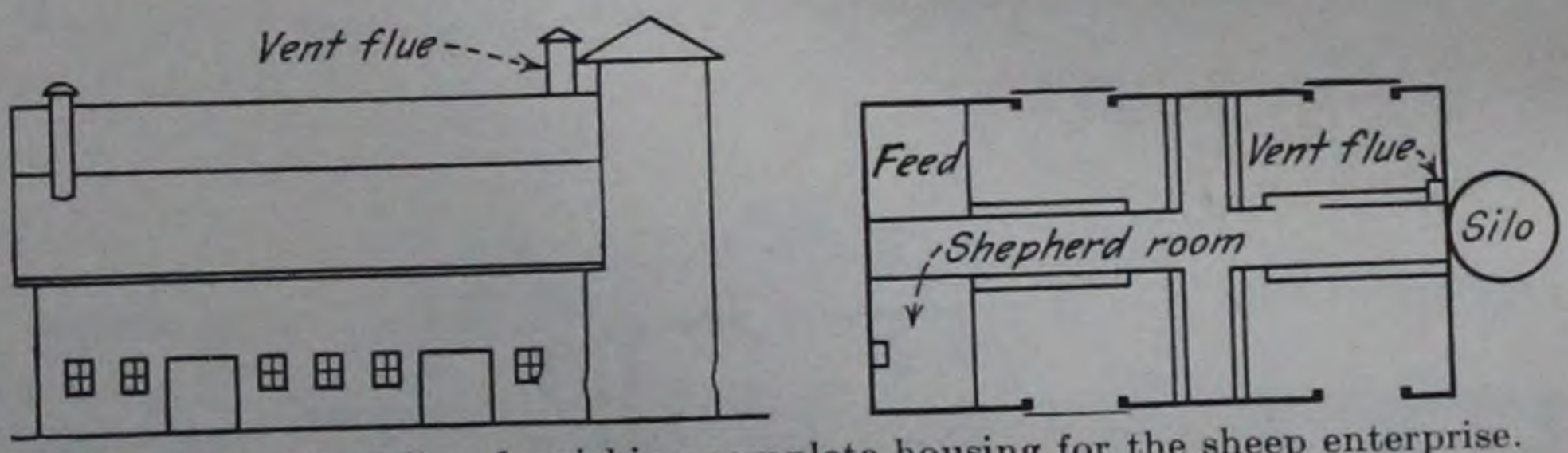


FIG. 56.—A building furnishing complete housing for the sheep enterprise.

provides three air changes per hour. Pen partitions and mangers are removable so that the barn may be divided as the need arises. Space is provided for 50 tons of hay, 200 bu. of corn, 100 bu. of oats, and 80 tons of silage.

54. Dipping Vats for Sheep.—Where the sheep enterprise on a number of farms is not large enough to warrant each farmer's providing dipping equipment, a portable vat is recommended. The cost to any one farmer in the group using a portable vat will be small, and this essential service will be available. The Midwest Plan Service[1] has prepared a plan for a stationary dipping vat for hogs or sheep. The size of the sheep or hog enterprise will determine the advisability of installing such equipment.

Questions and Problems

58. Discuss the different types of beef-cattle enterprises and the environments needed for each. How do these compare with the dairy enterprise?

[1] A farm building-plan service prepared by 15 Midwestern colleges and universities and the Bureau of Agricultural Engineering of the U.S. Department of Agriculture.

59. Discuss the type of building needed for each different branch of the beef-cattle industry.

60. How can the handling of feed, bedding, and manure be facilitated in each of the different types of buildings?

61. Give the good and the bad features of the barn designed for the cattle-feeding enterprise shown in Fig. 53. For the barn with limited hay storage shown in Fig. 51.

62. What are the important points to be considered in planning buildings for the sheep enterprise in building zone 3? In zone 2?

CHAPTER XIII

WORK-STOCK AND GENERAL-PURPOSE BARNS

BARNS FOR WORK ANIMALS

The sanitary requirements for structures in which to house work animals are not so exacting as those for the dairy barn, but the need for convenience in doing chores and in handling the stock and equipment used is worthy of study and planning.

55. The conventional type of barn with hay and bedding stored in the second floor is the most common (see Fig. 57).

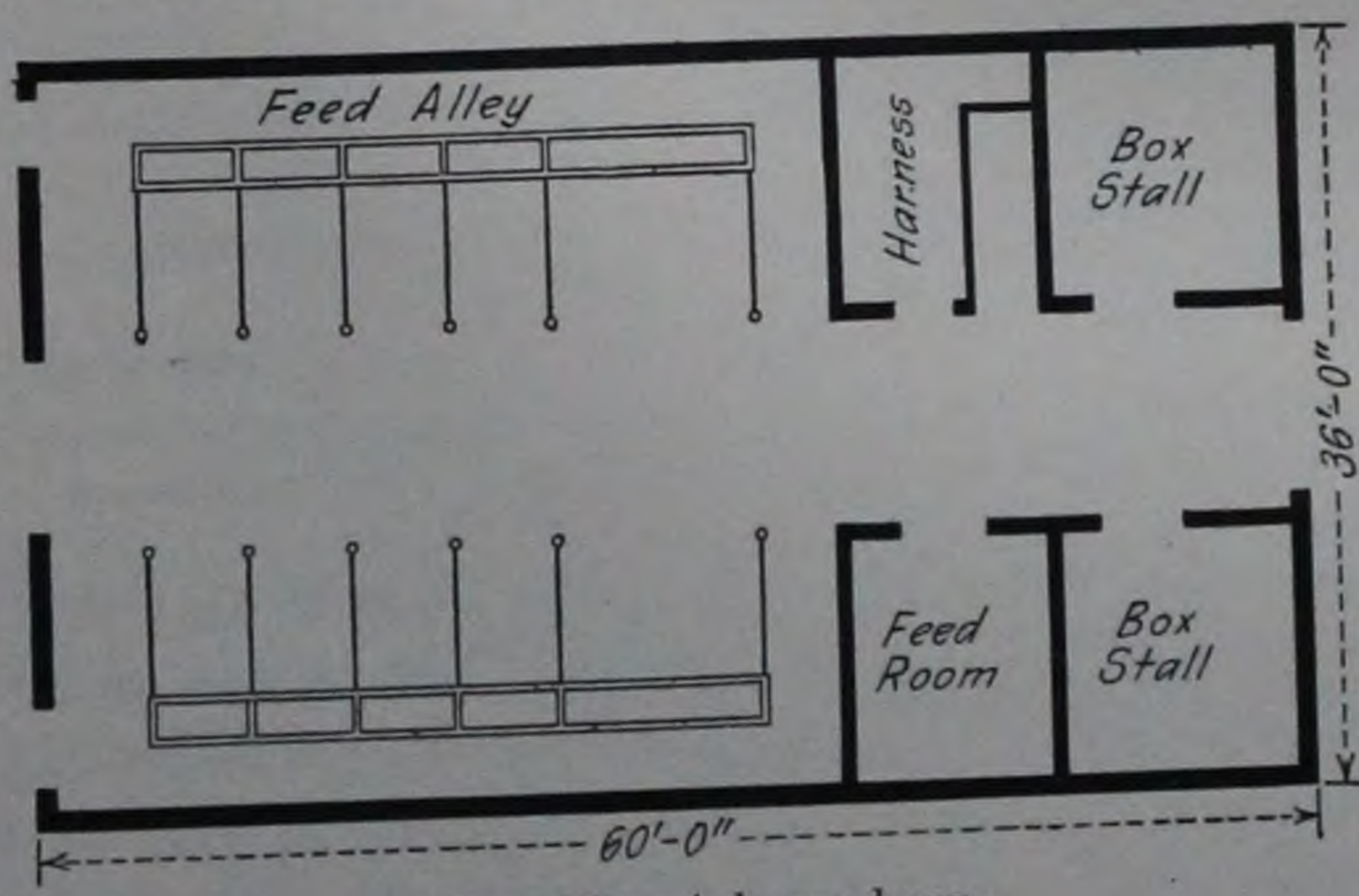


FIG. 57.—A horse barn.

As in the case of the other barns, the animals may be faced in to a central feed alley or out from a central service alley. Facing the animals in saves time in feeding but makes it necessary to divide them at stabling time. It is inconvenient where harness is used on different animals, and the work of cleaning the barn and disposing of the manure is made more difficult. Facing stock out from a central service alley shows the animals to a better advantage and makes the operations of cleaning the barns, caring for harness, grooming the animals, and handling larger teams a little more convenient.

Since certain equipment is used with teams, such as wagons and spreaders, it seems that such equipment might be stored to

advantage in the same building with the horses. In many of the English-type barns this equipment is stored on the first floor and the horses are kept in the basement. Such an arrangement can best be used where the topography will make it possible to drive in on the second floor. Figure 58 shows a combination

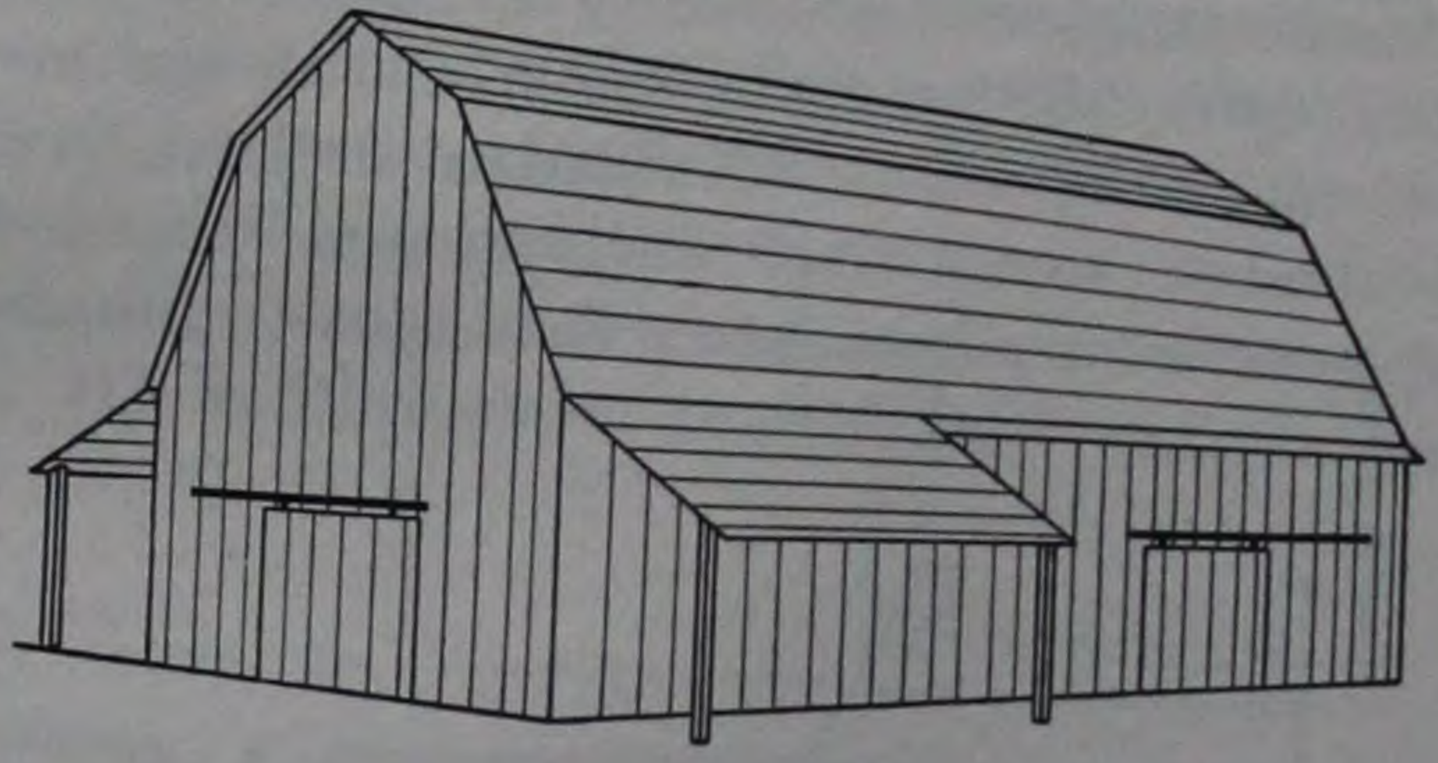


FIG. 58.—Combined horse barn and machinery-storage building.

horse barn and machinery-storage building. Room is provided for 6 horses, 250 bu. of corn, 500 bu. of oats, 20 tons of hay, and 10 tons of bedding. Drive-through sheds are shown for the spreader and one wagon, and space for the machinery found on the average farm is also provided in the building. Hay and bedding are stored on the second floor. The section for the horses should be built with double walls; the remainder should

be rain- and snow-proof but does not need to be insulated. Where the raising of horses or mules is one of the enterprises on the farm, a different type of barn will be desirable. With a change in manger design, length of stall, etc., the beef-cattle barn in Fig. 49 could be adapted to the needs of this enterprise.

Since horses are given more liberty to move about in their stalls than dairy cows, the necessity for special design in stall and manger is not so important. A standard stall can be used satisfactorily in most cases. Single stalls are usually made 5 ft. wide, and double stalls vary from 8 to 9 ft. in width. Standard height for mangers is 3 ft. 6 in., with an inside width of 2 ft. The stall

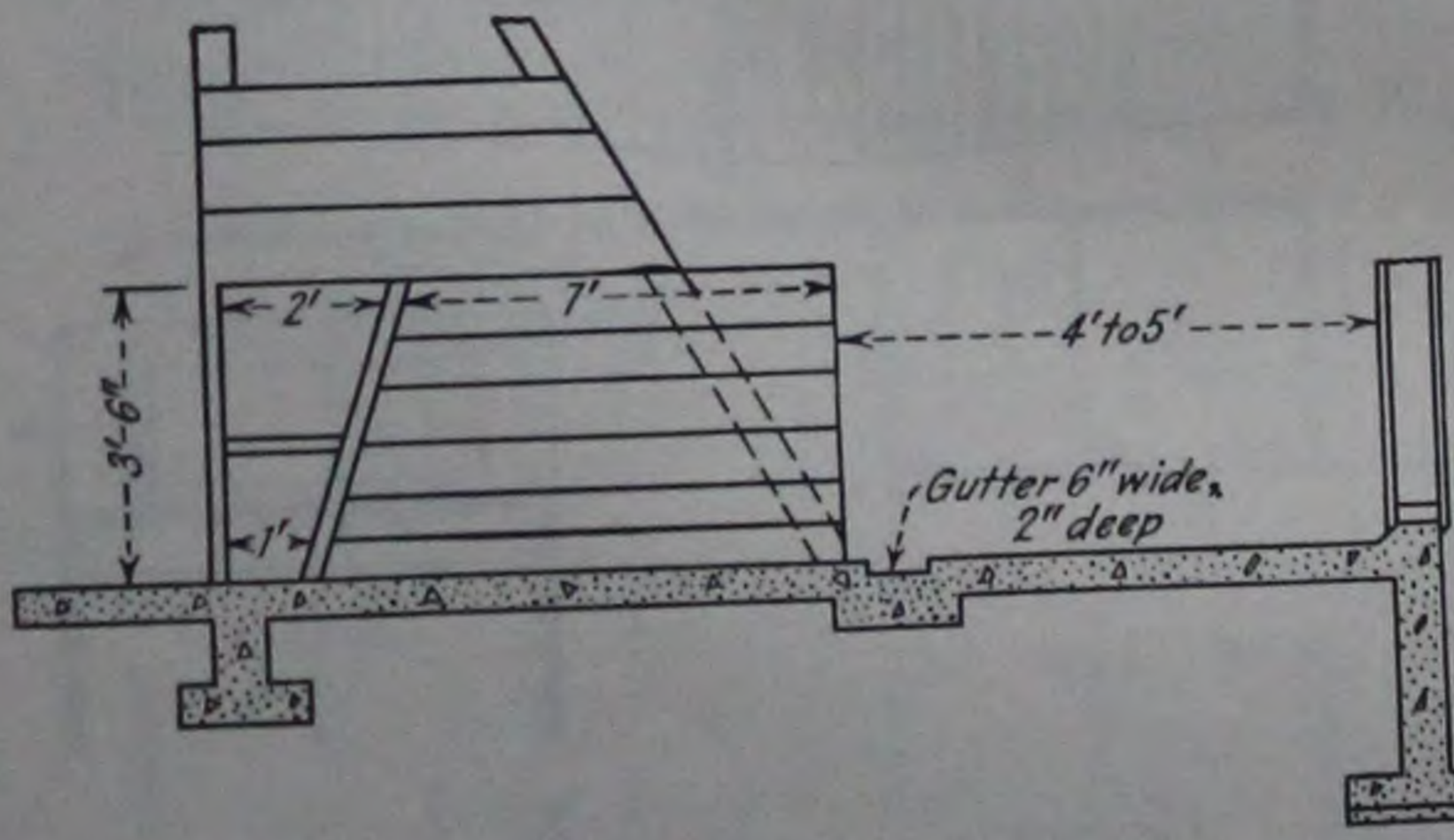


FIG. 59.—A standard horse stall.

length, including manger, is 9 ft. Floors in standing stalls should be of wood planks or wood blocks. Wood planks laid on concrete with a slight slope, usually 1 in. in 9 ft., make a good floor. One box stall should be provided for each pair of brood mares kept. The minimum dimension for a box stall is 9 by 12 ft., with 12 by 12 ft. a more desirable size. The box stall may be arranged to be used as a double standing stall if desired. Figure 59 shows a cross section of a standing stall.

56. The Harness Room.—On the average farm the harness for each horse is placed on pegs in the wall directly back of the horse to which it is fitted. In the face-out barn a peg at the back of each stall partition is often used. This is not the best place to store the harness, but the saving of time resulting may be of greater importance than the more rapid deterioration of

the harness. Most harness rooms are not used for harness but as a catch-all for other things.

57. The general-purpose barn is the type used on a great many Midwestern farms. It is like any other piece of equipment that is planned to serve a general purpose; it cannot be ideal in every respect. The general-purpose barn on smaller farms, especially, is planned to house horses, dairy cows, and perhaps beef cattle, hogs, and sheep. If dairying is a principal enterprise on the farm, it should certainly be moved out of the

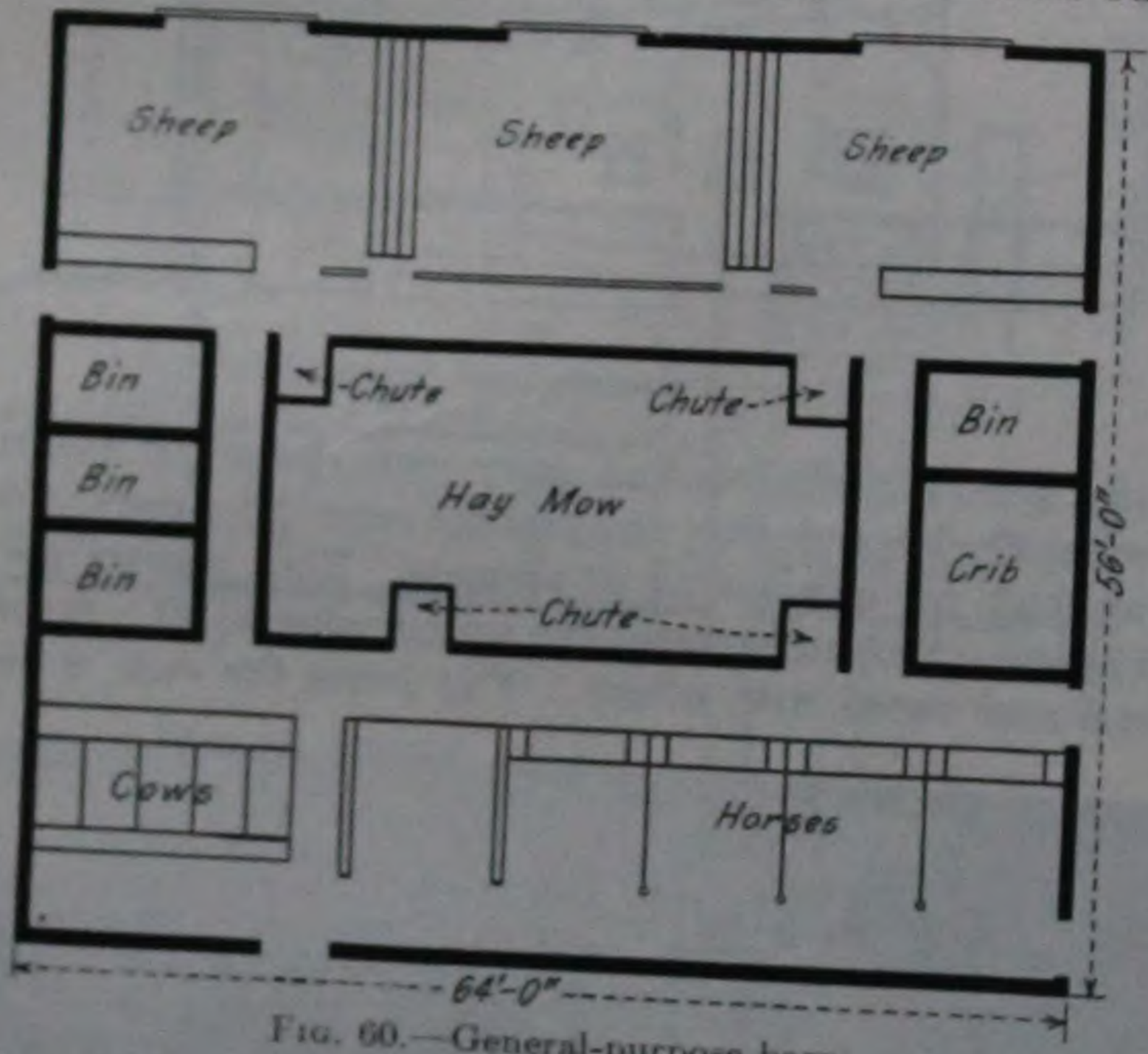


FIG. 60.—General-purpose barn.

general-purpose barn. It is difficult to secure the proper environment for hogs in the general-purpose barn, and in most cases they should be provided quarters suited to their needs. This leaves the horse, beef cattle, and sheep enterprises for the general-purpose barn.

Figure 60 shows a floor plan for a general-purpose barn to take care of horses, cows, and sheep, together with the season's feed supply. Such a barn is likely to be drafty unless solid division walls are built in to prevent too rapid air movement.

On a number of small farms the horse and the dairy enterprises are combined in one building. If a tight partition wall is built in between them the practice is permissible. Figure 61 shows a barn of this type.

"A firesafe, labor-saving livestock compound" shown in Figs. 62 and 63 was designed by E. L. Hansen of the Portland Cement Association.[1] A part of his description of the structure follows.

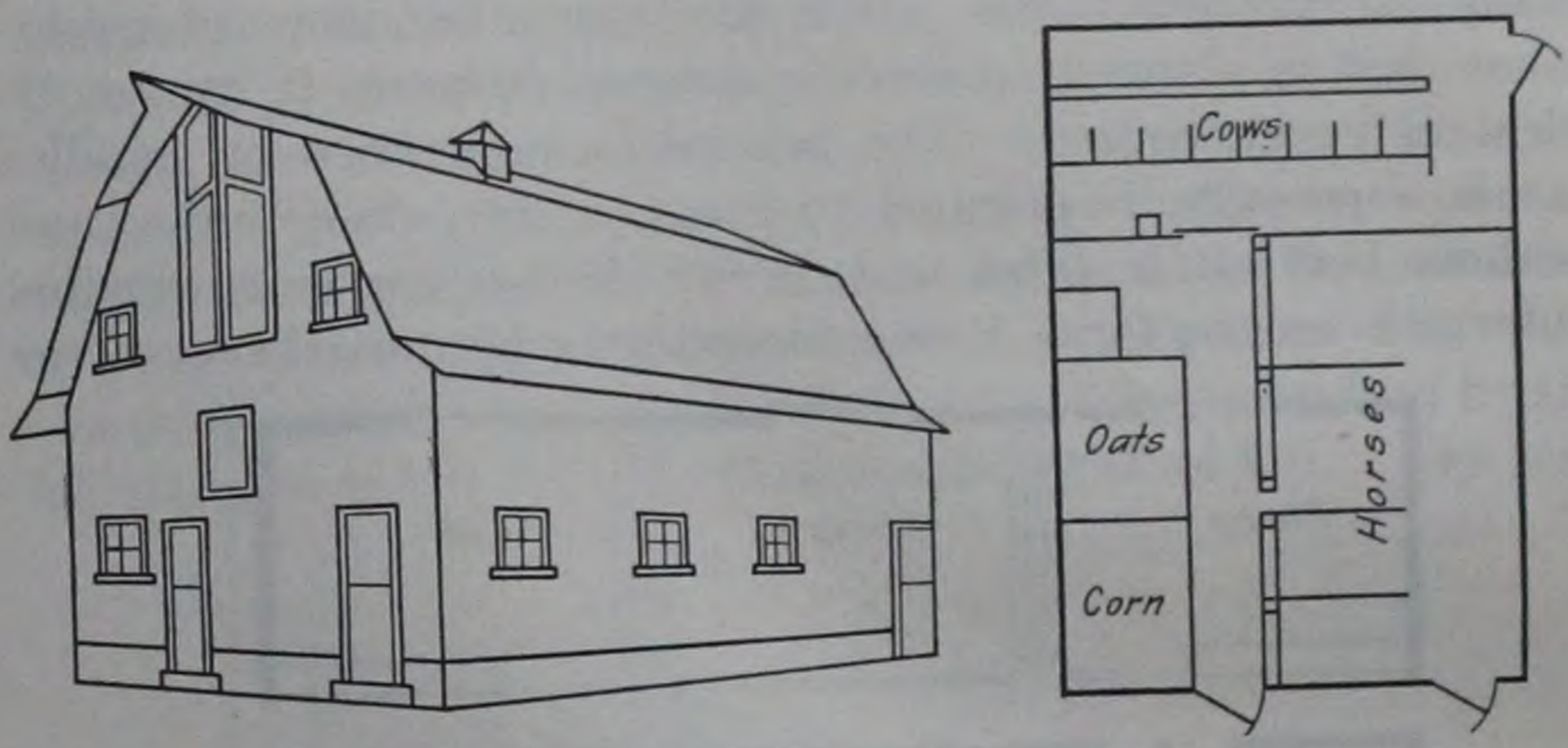


FIG. 61.—General-purpose barn for small farm.

On many general farms we find dairy cows, hogs and poultry; on others beef cattle, hogs, poultry and perhaps some dairy cows. We find that many feeds are common to all animals. Even poultry are being fed grass silage. Protein supplements are common to all. Some feeds are ground and mixed with others. This being the case, a common

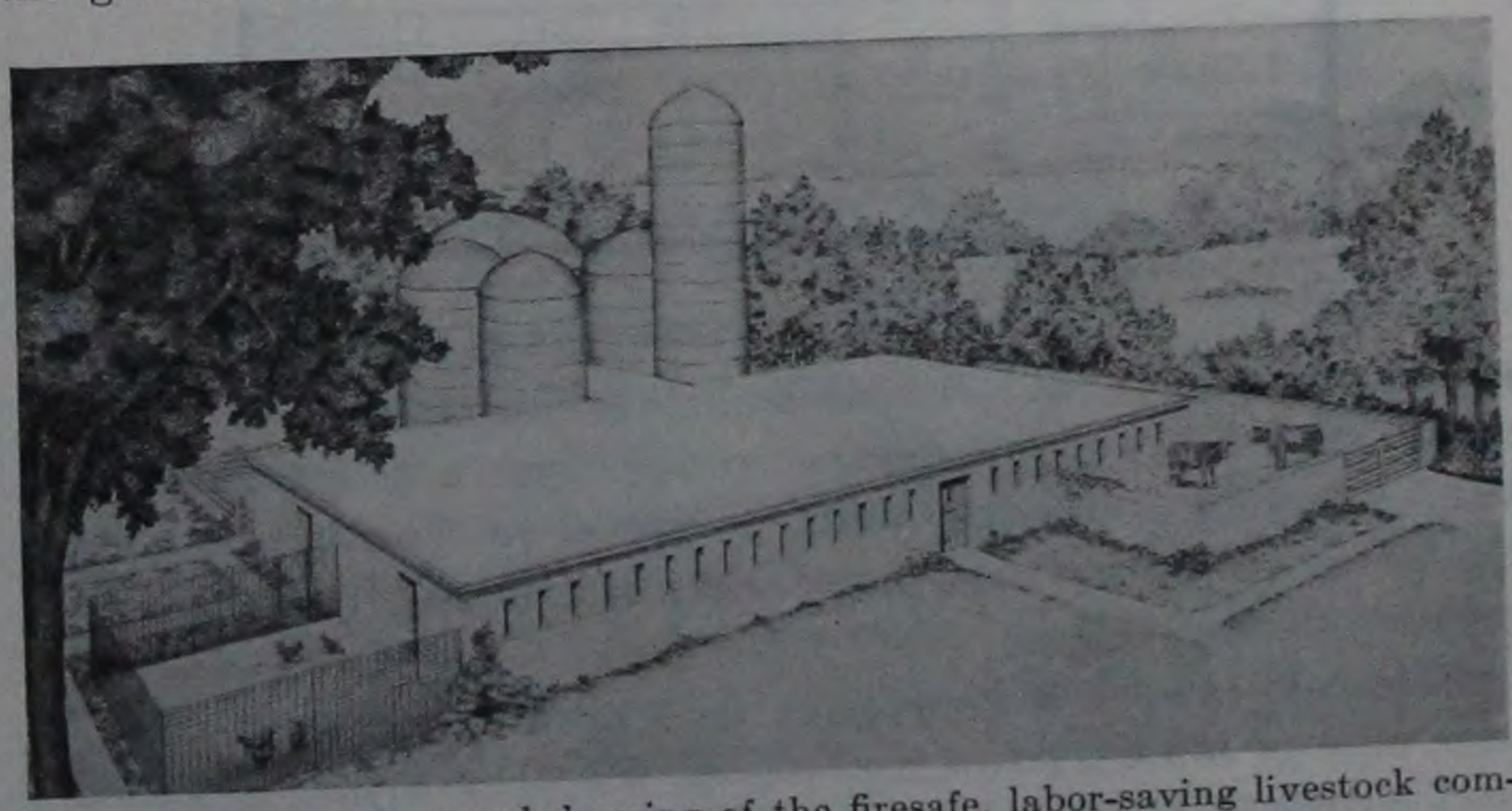


FIG. 62.—An architectural drawing of the firesafe, labor-saving livestock compound described by Hansen.

feed storage and room for mixing is desirable to utilize the same equipment for grinding, mixing, elevating and carrying feed.

The use of concrete and concrete masonry in farm buildings makes

[1] *Agr. Eng. J.*, Vol. 25, No. 11, p. 417, November, 1944.

possible sanitation and fire safety, which in turn makes it possible to combine buildings into one or two central plants that can be laid out for most efficient operation.

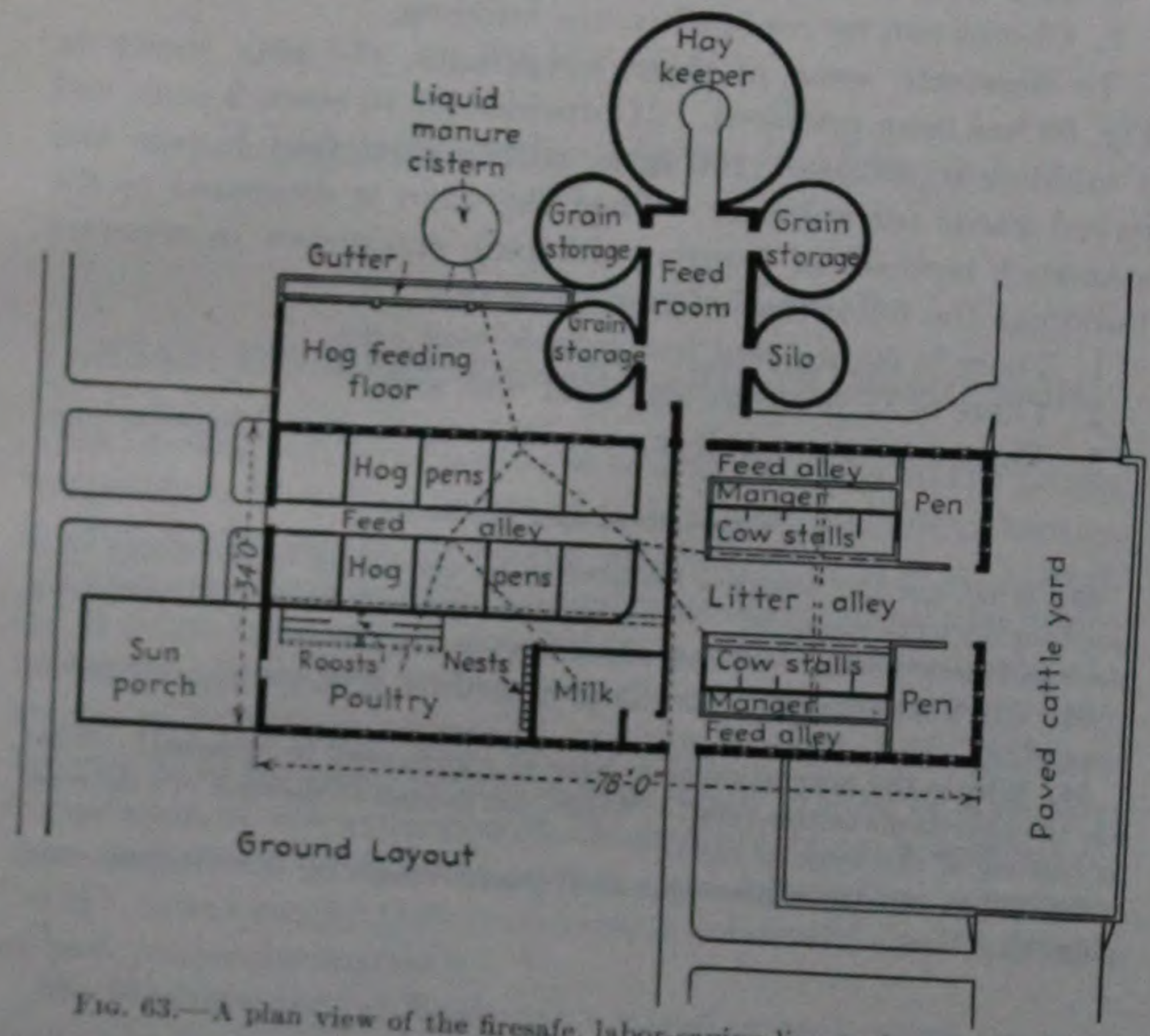


Fig. 63.—A plan view of the firesafe, labor-saving livestock compound.

ENGINEERING ADVANTAGES OF COMBINING FARM BUILDINGS

1. Less heat loss from buildings in winter because there are fewer outside walls.

2. Lower cost because some walls serve the purpose of two; interior walls need not be so heavy; less material is required for footings and foundation walls; less piping is required to provide running water to each unit; less wiring and fewer entrance installations are necessary to provide electricity.

3. Firesafe construction can be used, thus lowering insurance cost.

4. Light, ventilation, humidity, and temperature can be controlled at optimum conditions, using one system for all livestock units.

5. Work simplification; knowing the requirements for any particular farm it is possible to plan a layout for maximum efficiency.
6. Less land needed for the farmstead.
7. Chores can be confined to one building.

To illustrate some of these advantages, the plan shown in Fig. 63 has been prepared. It provides for 10 cows, 2 pens, and a milkhouse, 10 sows, 100 hens, with central feed storage and paved yards for animals. When this plan is compared to the standard method of housing different enterprises in separate buildings the following is found to be true.

1. There is 60 per cent less outside wall area.
2. There is 37 per cent less total wall area.
3. There is 50 per cent less material in footings and foundations.

Questions and Problems

63. What are the essential features to be considered in the design of a building for work animals? What are the arguments in favor of combining the machinery-storage building with the work-stock barn?

64. What are the essentials of a good stall for work stock? For saddle horses?

65. Why is the general-purpose barn so widely used in Missouri? What are the objections to this type? Would you predict an increase or a decrease in the use of this type of barn?

66. What are the advantages and disadvantages of the livestock compound?

PART III

Air-conditioning Farm Buildings

CHAPTER XIV

HEAT: ITS MEASUREMENT AND TRANSMISSION

To air-condition any building is to bring air in it to the proper temperature, humidity, degree of purity, and amount of motion to provide comfort for the people, animals, or fowl to be housed.

To become familiar with the general problem of air conditioning, it is first necessary to know how to measure heat and compute its movement through different mediums. Heat has long been known to be a form of energy and not a substance. Modern theories as to the exact nature of heat conceive it to be a motion or agitation of the molecules of which every body is composed. Every substance contains some heat, and to say that a body is "cold" means simply that it contains a relatively small amount of heat (molecular motion).

58. Measurement of Heat.—In measuring heat, there are two factors to be considered: *intensity* or potential rate of transfer and *amount*. A small piece of white-hot metal may not contain so great an amount of heat as a pail of warm water, but the intensity of the heat in the metal is much greater. The measurement of intensity, or temperature, is based on some arbitrary scale, such as that on the Fahrenheit or Centigrade thermometers. The quantity of heat must be measured by the effect that it produces on some substance. The unit of heat used in modern engineering practice is the *British thermal unit*, denoted by the symbol *Btu*, and is the quantity of heat necessary to raise the temperature of 1 lb. of water 1°F. However, since the heat required is not exactly the same at all temperatures, it is necessary to specifiy further a definite temperature at which the unit is to be established. The practice of different authorities varies in

this regard, but the Btu is the unit most generally used. It is defined as the 180th part of the heat necessary to raise the temperature of 1 lb. of water from 32 to 212°F.

In the field of nutrition, the unit most commonly used is the *calorie*. The calorie is the amount of heat required to raise 1 g. of water 1°C. Biologists use a unit called the *large calorie* or the *kilogram calorie*. This unit is equal to 1,000 cal. To change large calories to Btu, multiply the number of large calories by 3.968.

Heat may be transmitted in three ways: by radiation, by conduction, and by convection.

59. Radiation.—Heat is transmitted through *radiation* by a motion or vibration of the ether that is believed to pervade all space. Radiant heat follows the same physical laws as radiant light traveling in straight lines. Heat shadows may occur just as light shadows do, and the intensity of radiant heat is inversely proportional to the square of the distance from its source. Some substances are transparent to radiant heat; others are opaque to it. Radiant heat does not affect the medium through which it passes. For example, the atmosphere is not perceptibly warmed by the sun's radiant heat transmitted to the earth.

60. Conduction.—If one part of a body is at a higher temperature than another part, there will be a flow of heat through the body. The transmission of heat in this manner is known as *conduction*. A familiar example of this phenomenon is the flow of heat along an iron bar, one end of which is heated in a fire. The capacity of different materials to conduct heat differs considerably. Metals are the best conductors of heat; such materials as wood, celotex, and other insulating materials are very poor conductors.

61. Convection.—When a body is in contact with a fluid of a lower temperature, the envelope of fluid surrounding the body becomes heated. As this fluid envelope is heated its density decreases, and it is forced to rise, giving place to the colder fluid from below. A continuous current is thus created and maintained over the surface of the body. This process of heat transfer is called *convection*. The essential characteristic of the process of convection is the continuous renewal of the fluid layer at the surface of contact. Heat transmission from a fluid or gas to a solid may be accelerated because of convection. An exam-

ple of this is the transfer of heat from the warm air of a room to the cold outside walls. The air, on giving up its heat, increases in density and falls, giving place to warmer air from above, producing a continuous downward current. Convection currents cause excessive heat losses through poorly insulated spots in a room, especially if these poorly insulated areas are near the ceiling.

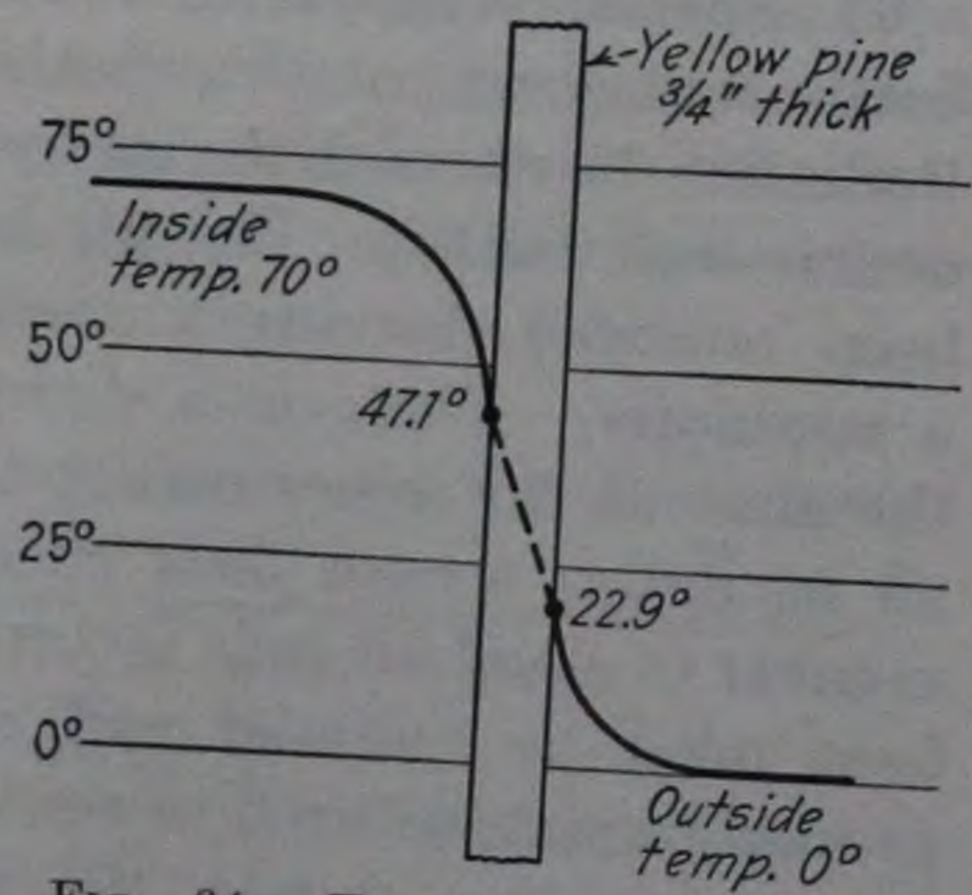


FIG. 64.—Temperature curve through a single wood separator with air on each side. If water were in contact with one or both sides, there would be no temperature drop at the surface or surfaces, and resistance to transfer of heat would be decreased.

62. Heat Transfer through Separating Mediums.—The transfer of heat through even a single sheet of material is a complex process. It involves the absorption of heat on the surface of the material, the conduction of heat through the material, and the radiation of the heat from the surface into the cold air (see Fig. 64). All these processes result in more or less resistance to the transfer. The greater the resistance of all combined, the smaller the amount of heat transmitted. Walls made from

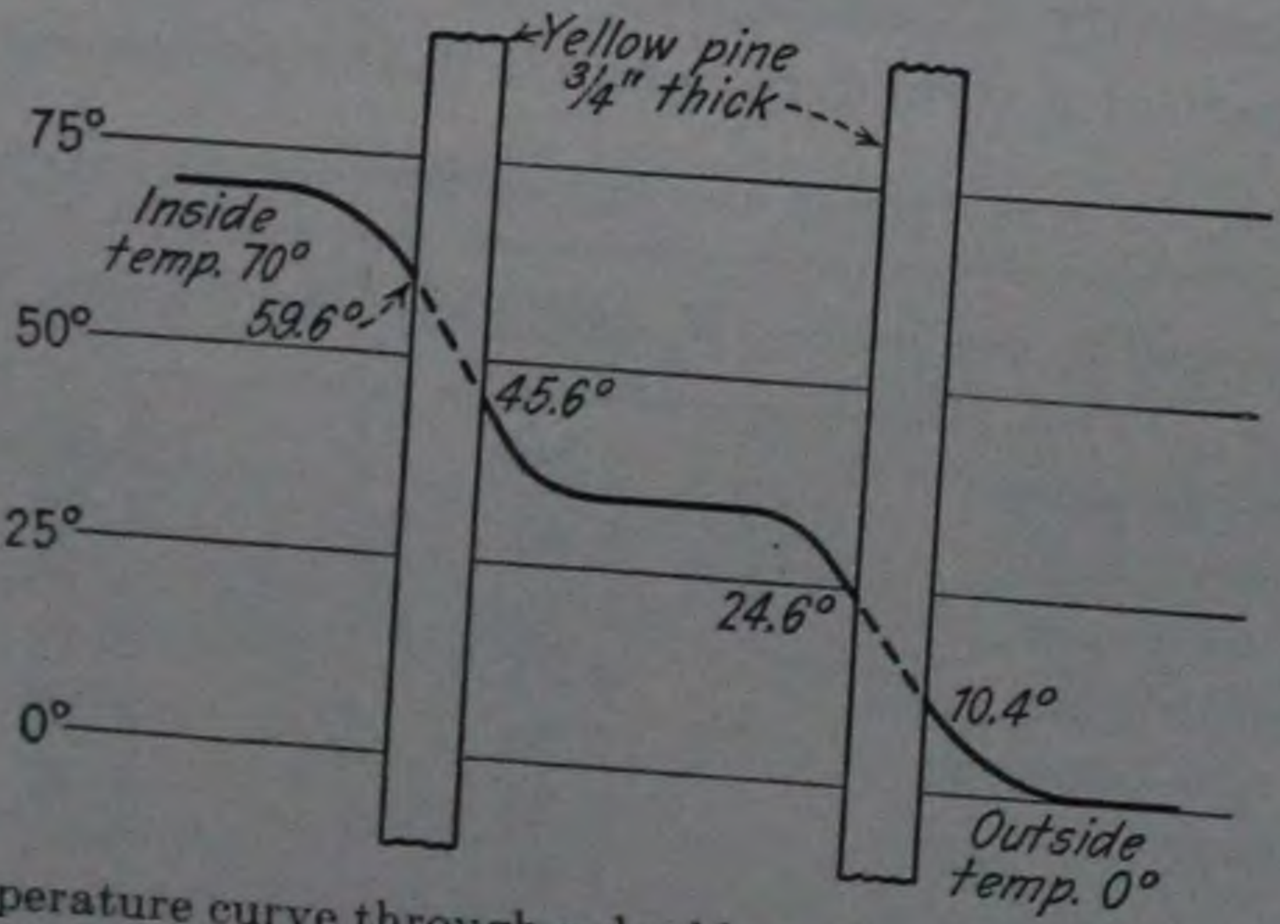


FIG. 65.—Temperature curve through a double wall with air on both sides and an air space in the center.

several different parts with air spaces between owe much of their insulating value to these resistances (see Fig. 65). If water, instead of air, is placed on each side of a wall, the effect of absorp-

tion and radiation is reduced to a minimum, and the heat transfer is dependent, quite largely, on the conductivity of the material in the wall.

63. Special Methods of Providing Insulation.—The Thermos bottle makes use of two methods of preventing heat transfer. Radiation has been reduced by silvering the inner surfaces of a double-wall bottle. The air between the two glass walls has been removed, leaving a vacuum that reduces conduction to a minimum. There is a slight amount of conduction through the glass at the upper end and through the cork itself. Nearly all insulators secure their effectiveness as a result of the large number of small air cells incorporated in the material so that the heat must be radiated and absorbed. Glass and rock, when properly manufactured to contain numerous air cells, make good insulators, even though the materials themselves have rather high coefficients of conductivity.

64. Computation of Heat Losses.—Not only must the designer understand how heat is transmitted through different mediums but he must be able to determine how much heat is transmitted in a given time interval. Before being able to compute this amount he must have a value for each of the surface and internal factors. Tables 20 and 21 give values for surface and internal conductivity coefficients.

65. Conductivity Coefficients.—The conductivity coefficient U for any part of a structure is equal to the reciprocal of the sum

TABLE 20.—COEFFICIENTS OF ABSORPTION AND RADIATION (K)

Material in surface	K_i (still air)*	K_o (15-mile wind)
Aluminum paint	.706	2.37
Brickwork, dry	1.40	4.70
Building paper	1.40	4.70
Cement plaster	0.93	3.12
Concrete 1-2-4 mix	1.30	4.37
Corkboard	1.25	4.20
Glass	1.50	5.04
Lead paint, black, flat	0.97	3.26
Lead paint, white	0.906	3.04
Magnesia board	1.45	4.87
Sheet asbestos	1.40	4.70
Wood	1.40	4.70
Zinc, galvanizing	.506	1.81

* To secure values of K_o in a 5-mile wind for any of the foregoing materials, multiply its K by 2.28; in a 10-mile wind, multiply by 2.96; in a 15-mile wind, multiply by 3.36; in a 20-mile wind, multiply by 3.62.

of the reciprocals of all the individual surface coefficients K and internal coefficients C affecting the transmission of heat (see Tables 20 and 21). (The reciprocal of the internal conductivity coefficient in each case must be multiplied by its thickness in inches.) The value of U is expressed in Btu of heat transmitted per hour per square foot of wall per degree (Fahrenheit) difference in temperature. The formula for U for different wall construction is usually expressed in the form shown in formula (1).

TABLE 21.—INTERNAL CONDUCTIVITY COEFFICIENTS FOR DIFFERENT MATERIALS

Material	C*	C_u†	U
Asphalt shingles	.....	6.50	
Brickwork, dry	4.00		
Cork (board or ground)	0.30		
Cement stucco	8.00		
Concrete 1-2-4 mix	8.30		
Cinder-concrete 1-2-4 mix	2.35		
Clay tile, 8-in. hollow	.....	0.43	
Glass, single	0.60	.....	1.13
Glass, double	.....	....	0.45
Glass, triple	.....	....	0.28
Insulation board, average	0.34		
Insulation quilt, average	0.26		
Pine, white, across grain	0.784		
Pine, yellow, across grain	1.00		
Rock wool	0.27		
Sawdust, ordinary	0.41		
Straw, cut dry	0.70		
Shavings, ordinary	0.41		
Sheet metal	.....	....	1.20
Wood lath and lime plaster	.....	2.00	

* C = conductivity coefficient per inch of thickness.

† C_u = conductivity coefficient for material as it is commonly used. When C_u is given, use $1/C_u$ instead of x/c.

Example: If the simple wall in Fig. 64 were made of white pine 2 in. thick, surfaced on both sides, with a 15-mile wind blowing on the outside of the wall, the values of U would be found by substituting the proper values in the formula

$$U = \frac{1}{\frac{1}{k_i} + \frac{x}{c} + \frac{1}{k_o}} \qquad (1)$$

where k_i = the surface coefficient for inside or still air.
x = the thickness of the material in inches.
c = the material coefficient.
k_0 = the surface coefficient for outside air.

Substituting, we have

$$U = \frac{1}{\frac{1}{1.4} + \frac{2}{0.784} + \frac{1}{4.7}} = \frac{1}{0.714 + 2.551 + 0.213} = 0.288$$

The formula for U for the double wall shown in Fig. 65 would be

$$U = \frac{1}{\frac{1}{k_i} + \frac{x}{c} + \frac{1}{k_i} + \frac{1}{k_i} + \frac{x}{c} + \frac{1}{k_o}} \tag{2}$$

If the wall is of white-pine boards ¾ in. thick, the value of U would be

$$U = \frac{1}{\frac{1}{1.4} + \frac{¾}{0.784} + \frac{1}{1.4} + \frac{1}{1.4} + \frac{¾}{0.784} + \frac{1}{4.7}} = 0.234$$

Computation of the heat loss through the ceiling and roof of a house requires consideration of the fact that there are two separate and distinct parts having different areas through which the heat must pass in escaping from the house. The following formula for such construction is suggested in "Heating and Ventilating Engineers' Guide."

$$U_{ac} = \frac{U_a U_c}{U_a + \frac{U_c}{R}} \tag{3}$$

where U_{ac} = conductivity coefficient for the combined ceiling and roof construction in Btu per hour per degree F. in difference in temperature per square foot of ceiling area.
U_a = weighted conductivity coefficient for the roof and gable ends combined.
U_c = conductivity coefficient for the ceiling.
R = ratio of roof to ceiling area.

In some cases the roof area may be equal to the ceiling area, and the formula becomes

$$U_{ac} = \frac{U_a U_c}{U_a + U_c} \tag{4}$$

The formula in this form may be used also to compute conductivity coefficients for units, walls, etc., composed of materials whose U values are known and the materials placed in such manner that escaping heat must pass through each of them.

Types of wall construction differ greatly, and no attempt will be made to list the values of U. They may be computed or taken from a reliable handbook.

Questions and Problems

67. A number of all-metal houses have been built in the South. They are sided outside and surfaced inside the studding with 28-gauge metal. What would be the value of U for the wall?

68. A brooder house 10 by 12 ft. is built with a double wall; ¾-in. yellow-pine car siding is used to cover the outside of the studding, and the inside is lined with ½-in. celotex. With a 15-mile wind blowing, what would be the value of U for the wall?

If 4-in. rock-wool insulation were used between studding, what would be the value of U?

69. The ceiling in a house is covered with lath and plaster, and the attic is quite open, resulting in practically outside temperatures. The walls consist of lath and plaster on the inside of the studding and sheathing, paper, and weatherboard on the outside. The owner wishes to distribute the investment in *insulation* over a period of three years. What should he do the first, second, and third year?

70. The walls of a concrete cooling tank are made of two 2-in. layers of concrete separated by 2 in. of ground cork. The tank is partly filled with water. What would be the value of U above the water? Below the water level?

71. A dairyman has a milk-cooling tank 26 in. deep, 40 in. wide, and 60 in. long (inside measurements). The walls are made as for the tank in problem 70. The lid to the tank has a value of $U = 0.14$. When five 10-gal. cans of milk are placed in the tank, the water level is 6 in. below the top of the walls. If the milk is placed in the tank of a temperature of 70°F., cooled, and held at 40°F., when the outside temperature is 90°F., how much ice will be required in a 24-hr. period? (Neglect the loss through the floor.) Milk has a specific heat of 0.87 and weighs 8 lb. per gallon. The heat of fusion of ice is 144 Btu per pound.

CHAPTER XV

THE ENVIRONMENT FOR COMFORT

66. Reaction of the Animal to Environment.—From the point of view of the physiologist, a comfortable environment is one in which the body temperature can be controlled by *physical* means. These physical means consist of diverting a greater or lesser amount of the blood to the surface or away from the surface as the body temperature needs to be lowered or raised. In the case of sweating animals, the production of sweat on the body surface and the resulting evaporation serve to lower the body temperature. A need for an increase in body temperature is shown when the hair or fur coating of an animal stands up, making a thicker protective covering, resulting in a reduction of heat loss. If these physical means fail to control body temperatures and if additional feed must be oxidized to supply heat to maintain body temperature, the environment does not supply all the needs for comfort. If the temperature is too high for comfort the rate of respiration is increased, and additional moisture is exposed to the air for evaporation through sweating or through the respiratory system.

67. Influence of Temperature and Humidity on Comfort.—The effect of moderately warm, humid air is that of a higher temperature than the thermometer indicates.[1] When the atmosphere is near the point of saturation, the evaporation that usually goes on from the surface of the body practically ceases, causing the sensation of warmth. In summer a temperature of 85°F. with a relative humidity of 90 per cent seems warmer than a temperature of 100° with 40 per cent relative humidity because of the cooling effect produced by the increased evaporation resulting from the higher temperature and the drier air. Most people recognize the "balmy" air of June without realizing just why, at the same temperature, other seasons are not so delightful. In reality, it is the condition of atmospheric humidity combined

[1] KEENE, E. S., "Mechanics of the Household," Chap. X, McGraw-Hill Book Company, Inc.

with an agreeable temperature that gives the kind of air in which we find the greatest degree of comfort.

It is during the cold season that we are most affected by low relative humidities. When saturated air at 10°F. is brought into a room it contains 1.11 grains of moisture. When heated to 70°, it has the capacity to hold 8 grains. Its relative humidity is then 1.11/8.00, or practically 14 per cent. This is very dry air, and it will cause rapid evaporation from all surfaces with which it comes in contact. Sufficient moisture should be added to bring the relative humidity up to at least 50 per cent. Warm-air furnaces are usually equipped with water evaporators to provide the desired humidity. With hot-water or steam-heating systems, humidifiers are attached to radiators. They are usually arranged to hang behind the radiator so as not to be unsightly.

68. Importance of Carbon Dioxide Content.—Experiments reported in a master's thesis at Cornell University give further information on the question of comfort.[1] According to data obtained from these experiments, it would seem that the important thing in securing comfort is the preservation of the cooling power of the air to which the person or animal is exposed.

One of the experiments conducted consisted in crowding as many young men as possible into an airtight cabinet provided with an observation window and an electric fan. No discomfort was felt for some time, but after 44 min., when the dry-bulb thermometer stood at 87°F. and the wet bulb at 83°F., the conditions here quoted were obtained:

> The discomfort felt was great; all were wet with sweat and the skin of all was flushed. The talking and laughing of the occupants had gradually become less and then ceased. On starting the electric fans and whirling the air in the chamber the relief was immediate and very great, although the carbon dioxide content had risen to 5.26 per cent and the oxygen had fallen to 15.1 per cent. On shutting off the fans the discomfort returned. The occupants cried out for the fans. No headaches or after-effects have followed this type of experiment, which has been repeated five times.

In further experiments it was found that when a person *outside* the chamber breathed through a gas mask connected with

[1] HEIHPEL, L. G., "A Comparative Study of the Effectiveness of King and Rutherford Systems of Stable Ventilation as in Use Near Montreal, Canada," a thesis presented to the faculty of the Graduate School of Cornell University for the degree of Master of Science, September, 1930.

wide-bore tubing to the inside of the chamber no symptoms of discomfort developed, even at the time when the persons inside the chamber were overcome. Again, when an occupant of the chamber breathed air from outside the chamber through a gas mask, he suffered the same symptoms as the others. In the light of the evidence at hand, the importance of the standard of purity of the atmosphere, so far as carbon dioxide content is concerned, has been very much overestimated.

69. Effect of Air Motion.—The influence of air motion on comfort was shown in the foregoing tests. The use of the fans brought relief even though the humidity and temperature remained unchanged. The influence of different rates of air movement on comfort for dwellings is shown in Table 22. The temperature for comfort with different rates of air movement and different relative humidities is given.

This accounts for the fact that we use a fan in summer to secure relief from high temperatures. The movement of saturated air away from the surface of the body and the introduction of air of lower relative humidity promote more evaporation from the surface and consequently cause a greater withdrawal of heat from the body.

TABLE 22.—EFFECT OF AIR MOVEMENT ON TEMPERATURE FOR COMFORT*

Wet-bulb temperature, degrees F.			Dry-bulb temperature, degrees F.			Air velocity, feet per minute
20% R.H.	50% R.H.	80% R.H.	20% R.H.	50% R.H.	80% R.H.	
51.5	57.5	61.0	71.0	69.5	68.0	Still air
52.5	60.0	65.0	74.0	71.5	69.0	100
54.0	61.5	66.5	76.0	73.0	71.0	200
55.0	63.0	68.0	78.0	75.0	73.0	300
56.0	65.0	70.0	97.0	77.5	74.5	500

* For persons normally clothed and slightly active. If occupants are inactive, temperatures should be increased 10 per cent. Adapted from "Heating and Ventilating Engineers' Guide," American Society of Heating and Ventilating Engineers, New York City.

In a dairy barn of average construction, where the heat given off by the animals housed is sufficient to maintain comfort with an outside temperature of zero or lower, the relative humidity of the air will approach the saturation point long before the

carbon dioxide content is high enough to be taken into consideration. It would appear then that relative humidity, temperature, and air movement form the most reliable guides as to the environment for comfort furnished by any structure.

70. Building Zones.—The comfort zone is different for people at work and at rest, just as it is different for dairy cows and for beef cattle. The comfort zone for any one kind of animal no doubt varies from one section of the country to another. Dairy

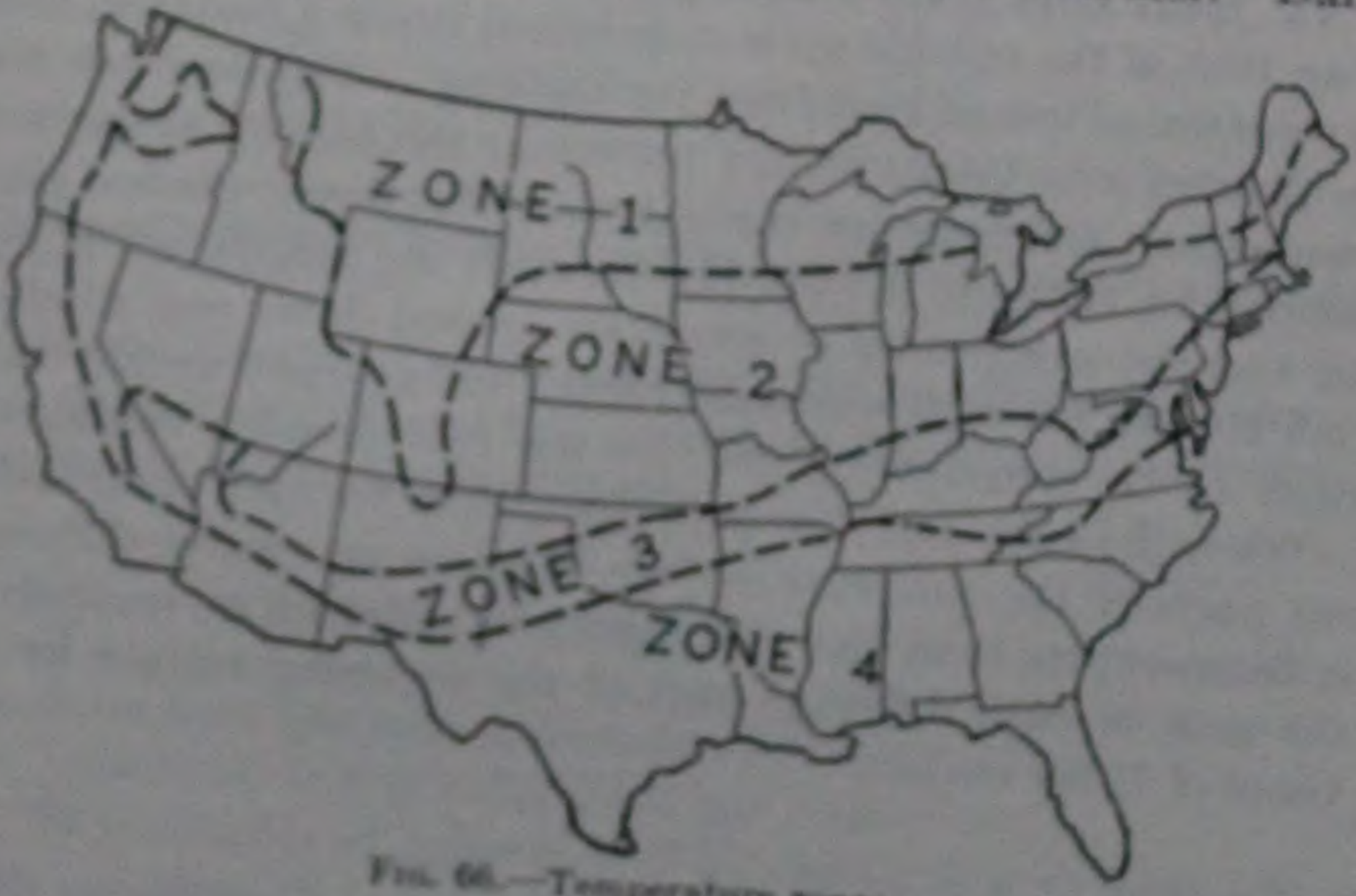


FIG. 66.—Temperature zones.

cows in Canada would probably be comfortable at lower temperatures than would cows in Missouri.

For the benefit of designers the United States has been divided according to climatic conditions into temperature zones[1] (see Fig. 66). Zone 1 has an average of 154 days per year when the minimum temperature is 32° or less; zone 2, 107 days; and zone 3, 64 days. The lowest sustained temperature in zone 1 is −32°; in zone 2, −7°; and in zone 3, +10°. In securing the lowest sustained temperature for any section, it has been suggested that a 10-day chain average be used on daily temperatures throughout the season and the lowest chain-average temperature secured during the winter considered to be the lowest sustained temperature.

[1] CLARKSON, W. B., and C. S. WHITNAH, Climatic Dairy Barns, *Agr. Eng. J.*, Vol. 1, No. 2, February, 1920.

71. Need for Conservation of Heat.—When the temperature drops to 50°F., some protection is necessary for dairy cows, and when the outside temperature reaches 32°, definite measures must be taken to conserve heat in dairy barns. Before intelligent plans can be made to conserve heat, the amount of heat available and the amount lost from the structure during the period of lowest sustained temperature must be known.

72. Heat Loss from Buildings.—When a temperature higher than that of the outside air is maintained inside a building, there is a continual loss of heat from the building. This heat loss may be divided into three distinct parts: (*a*) the loss by absorption, conduction, and radiation through the walls, floors, window glass, doors, and ceilings; (*b*) the loss through the infiltration of cold air and the exfiltration of warm air around doors and windows (infiltration through well-constructed walls is not usually sufficient to be considered); and (*c*) the loss through ventilation.

When the value of U has been determined for each of the different parts of the enclosing surface, the loss per degree difference in temperature from this source may be obtained by multiplying the area of each different part of the enclosing surface by the value of U for each.

$$H_w = AU \tag{5}$$

where H_w = heat loss through walls per hour per degree difference in temperature.
A = area of wall surface in square feet.
U = coefficient of conductivity for the wall (minus windows and doors).

(H_g, the loss for glass area, H_d, the loss for doors, H_c, the loss for ceilings, etc., can be computed in a similar manner.)

73. Infiltration and Exfiltration Losses.—In most structures there is air leakage through the walls, especially under extreme differences in temperature or during periods of high wind pressure. With up-to-date construction, however, these air losses through walls are not considered of sufficient importance to be included in computations. The losses through cracks around windows and doors are very important, however, and must be considered in computations of heat losses. Table 23 gives the amount of this infiltration under different wind velocities with and without weather stripping.

TABLE 23.—INFILTRATION AROUND DOORS AND WINDOWS*

Wind velocity, miles per hour	Leakage, cubic feet per hour per foot of crack	
	Plain windows	Weather-stripped
5	39.3	3.00
10	84.9	11.70
15	124.0	22.90
20	161.0	34.90
30	233.0	59.60
40	309.0	87.80

* Figures may be slightly low for figuring infiltration around doors, but if the construction is good they will be satisfactory.

When the amount of infiltration in cubic feet has been determined, the amount of heat loss per degree difference in temperature may be determined as follows:

$$H_I = \frac{I}{53} d \qquad (6)$$

where H_I = heat loss from infiltration per hour.
I = cubic feet of infiltration per hour.
53 = number of cubic feet of air that 1 Btu of heat will raise 1°.
d = difference in temperature inside and outside the building.

74. Heat Loss through Ventilation.—In most dwellings no special apparatus is installed to provide ventilation. The draft of furnaces, the fireplace, general infiltration, and the use of windows and doors are expected to provide the required air change. The accepted average quantity of fresh air to be supplied per person is 1 cu. ft. per second per person, or 3,600 cu. ft. per hour per person. This rate assumes a standard of purity of less than 2 parts in 10,000 of carbon dioxide more than that carried by country air. This is a high standard and is not often attained in residences on account of the heat loss that would result from so much air change. However, it is a generally recognized fact that pure air is necessary to health, and some effort is made to keep the air reasonably pure. The fireplace, if it has no other value, is worth its cost for the ventilation it provides.

In modern barns and poultry houses, some provision is made for ventilation in order to provide comfortable conditions. A definite amount of inside air is exhausted, and a like amount of fresh air is admitted each hour. The heat loss per degree difference in temperature through this change is computed as for infiltration:

$$H_v = \frac{Q}{53} d \tag{7}$$

where H_v = heat loss through ventilation per hour.
Q = cubic feet of air change per hour through the ventilation system.
d = difference in temperature inside and outside the building.

75. The Weighted Value of *U* for a Barn.—It is sometimes desirable to know the weighted value of U for a barn as a whole. To determine this, the total heat loss through walls, windows, doors, ceiling and through infiltration for 1° difference in temperature is divided by the total area of exposed surface. This gives the weighted average value of U for the structure, not including ventilation.

76. The Probable Temperature of a Barn for Any Given Outside Temperature.—To determine this factor it will be necessary to compute the temperature difference that can be maintained and add this to the given outside temperature. This temperature difference can be computed by dividing the sum of all the heat losses per degree difference in temperature into the total heat available in the barn.

$$d = \frac{H_a}{H_w + H_g + H_c + H_d + H_i + H_v} \tag{8}$$

where H_a = heat available in Btu per hour.
d = temperature difference in degrees.

Example: A dairy barn housed 56 cows producing 182,000 Btu of heat per hour. The heat loss through walls was 1528 Btu; through glass, 190 Btu; through the ceiling, 340 Btu; through the doors, 77 Btu; through infiltration, 1986 Btu; and through ventilation, 2600 Btu per hour per degree difference in temperature. The heat available, 182,000 Btu, divided by 6721 Btu, the heat loss per degree, equals 27° difference in temperature that could be maintained.

Questions and Problems

72. Would a fan to cause greater air movement be equally valuable in producing summer comfort to the animals in a dairy barn and in a barn housing horses? Explain your answer.

73. If a piece of wet burlap were placed in front of a fan in a closed room would it aid in lowering the temperature of the air? Would it necessarily increase comfort? Explain.

74. In the Western states a cloth water bag that leaks sufficiently to keep the surface damp provides cold drinking water when hanging in the breeze, even though it may be in the hot sun. Explain. A tourist purchased one of these water bags in Idaho and reported it worked successfully until he reached eastern Kansas, when it began to leak and became covered with mud. Explain.

75. We should add moisture to the air of our homes in winter and remove moisture in summer to secure comfortable conditions in the Middle West. Is this statement true? Explain.

76. The air on a high mountain may contain less oxygen than the air in a poorly ventilated room; yet mountain air is considered beneficial. Is this correct? Is there any similarity in the effects of these two environments?

77. A dairy barn that is satisfactory for a farm and herd in Minnesota may not be suited to a farm and herd of equal size in Missouri. Explain, mentioning the different factors that would have an influence.

78. Inspection of a barn was made, and the following information was secured. What inside temperature would result when the outside temperature was zero with a 15-mile wind blowing?

HEAT LOSS THROUGH EXPOSED SURFACES

Name of exposed area	Material	Constructions	Area, square feet	*U*	Btu lost per degree difference in temperature per hour
Wall	Wood	¾-in. YP siding + air space + ¾-in. YP inside	1,095	.258	281.5
Wall	Concrete	8-in. thick (1-2-4) mix	783	.51	399.3
Windows	Glass	Single thickness	210	1.13	237.3
Doors	Wood	1½-in. white pine	183	.338	61.8
Ceiling	Wood	⅝-in. YP + air space + ¾-in. YP	3,220	.236	760.0
				Heat Loss through Infiltration	1719.9

Location	Feet of crack	Rate of infiltration per foot	Total		Btu loss per degree
Windows	308	124	38,192		720.0
Doors	172		21,328		402.0
					1122.0

Heat Loss through Ventilation

Air change, cubic feet per hour	Btu loss per hour
85,480	
Total Btu loss per degree per hour	

Heat Available

No. animals	Kind	Heat production per Btu per animal	Btu produced per hour
21	2-year-old	2,500	
18	1-year-old	1,500	
20	Calves	600	
14	Cows	3,400	138,900

CHAPTER XVI

HEAT AND MOISTURE RELATIONSHIPS

77. Production of Heat.—The heat used in making farm buildings comfortable in winter comes from the animals housed, with the exception of a few enterprises in which artificial heat may be used. Brooder houses for small chicks or young pigs and, in a few cases, laying houses, are heated artificially, but most barns and laying houses are designed to conserve the heat from animals and fowl and are dependent on that heat for comfort.

The amount of heat given off depends on four factors: the temperature of the surrounding atmosphere, the size of the animal or fowl, the amount of activity, and the amount of food being assimilated. Figure 67 shows the effect of environment on heat and moisture production of 4-lb. Leghorn hens.[1]

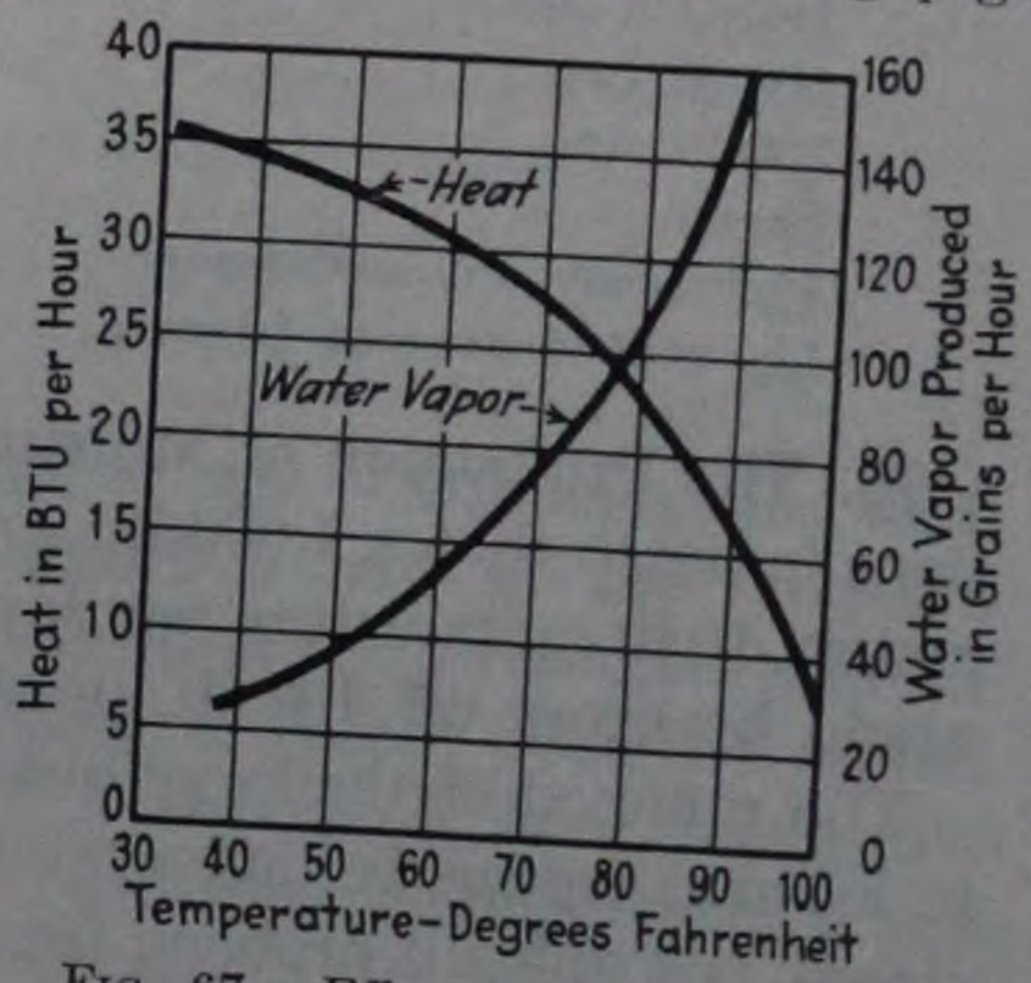


FIG. 67.—Effect of environment on heat and moisture production of 4-lb. Leghorn hens. As the temperature is lowered, the amount of heat given off is inereased and the moisture is decreased. At 50°F the heat production is 32.5 Btu per hour, a figure often used for Leghorn hens in production.

The amount of heat given off by any object, whether it be a bird, animal, radiator, or stove, depends on the kind and amount of surface exposed and the difference in temperature between this surface and the surrounding medium. The amount of surface on the body of an animal is difficult to measure, making this unit unsatisfactory for computation. However, experiments have shown that there is a definite relationship between weight and body surface and, therefore, between weight and heat production.

[1] *J. Agr. Research*, Vol. 47, No. 10, p. 734.

Since the temperature and humidity in farm buildings cannot be held to a certain point in all seasons, it is necessary for the designer to use a figure in his computations for heat production that will give satisfactory results under varying conditions. The figures given in Table 24 on heat production are averages and may be used in general design work.

TABLE 24.—HEAT PRODUCTION

Source	Btu per Hour
Adult person	400–500
Hen	25–35
Horse	1,800–2,500
Jersey cow	2,000–3,000
Holstein cow	3,000–3,500
100-lb. hog	400–450
200-lb. hog	750–850
Sheep	300–350
Electricity, kilowatt-hours	3,412
Lb. coal in average furnace	6,000

78. The Production of Moisture in Barns.—Recent investigations indicate that a 1,000-lb. cow breathes into the air approximately 10 lb. of moisture per day. From a herd of 40 cows there would be given off 400 lb. or about 50 gal. of water per day.[1]

The removal of the large quantity of moisture that is created in a barn, especially under winter conditions, when the barn is closed, is a difficult problem for the designer to solve. There are days in the summer when both temperature and relative humidity are high, and lowering the humidity, or perhaps both humidity and temperature, would add greatly to the comfort of the animals housed.

Most farm enterprises will not justify the expense of artificially air-conditioning the buildings, but several things can be done to improve conditions during hot summer weather. Insulation is often considered to have as much value for summer conditions as for winter, although the direct saving realized cannot be computed so readily. In addition to insulating buildings to keep heat out, we may provide shade by planting trees at proper points to give the desired results. Shutters built to act as insulators may be valuable on hot summer days and cold winter nights. If a barn can be equipped with a fan for circulating the air, the windows may be opened at night and closed during the day. By

[1] Beef Cattle Barns, *U.S. Dept. Agr., Farmers' Bull.* 1350.

operating the fan to circulate the air in the closed barn, a higher degree of comfort can often be secured than would be the case if the barn were opened during the day.

During the winter season moisture creates much more of a problem than in summer, because a free exchange of air between inside and out is not possible. Most designers are inclined to govern the amount of air change by the need for moisture removal. Table 25 gives information necessary in determining the amount of moisture to be removed.

TABLE 25.—VAPOR PRODUCTION

Source	Grains per Hour
Dairy cow	4,375
Farm horse	5,100
300-lb. hog	729
Sheep	486
Hen	35
Adult person	350

79. Moisture-holding Capacity of Air.—Although the feed, litter, and the building itself absorb a part of the moisture produced, most of the moisture is held in the air and is removed as the air is drawn from the building; or it may condense on the walls, windows, or equipment. A dairyman once made the statement that it "rained" in his barn when he opened the doors on a cold morning. The inside air was saturated at a temperature above that outside the structure, and when the doors were opened the cold air entering caused precipitation. Table 26 gives the maximum moisture-holding capacity of air at various temperatures.

80. Humidity has to do with the amount of moisture the air contains. If it is expressed as a per cent of its possible holding capacity it is called *relative humidity*. If air at 50°F. contains 2.14 grains of moisture per cubic foot it is said to have a relative humidity of 50 per cent, since it contains one-half of what it would contain if saturated at this temperature. If the term *absolute humidity* were used the air would be said to have an absolute humidity of 2.14 grains, the actual amount of moisture it contained per cubic foot.

It can be seen from Table 26 that the holding power of the air decreases as the temperature is lowered. If air at 75°F. having a relative humidity of 90 per cent were lowered to 40°F. there

would be condensation in the form of rain. If a cold-water pipe were introduced into this 75° air there would be condensation on the pipe coming from the air that was cooled around it; or if the walls of the room were cold enough so that the air in contact with them would be reduced beyond the dew point condensation would result. Windows are low in insulating value and are colder than other parts of the building. For this reason condensation first appears on the glass.

81. Condensation on windows and walls causes rapid deterioration of buildings and equipment through rotting or rusting of the materials. It produces unsanitary conditions in which to handle milk and results in a poor environment for livestock. Condensation depends on several factors: the relative humidity of the air, the temperature, the coefficient of absorption of the

TABLE 26.—MOISTURE CONTENT OF SATURATED AIR AT DIFFERENT TEMPERATURES

Temperature of air, degrees F.	Weight of vapor per cubic foot saturated air, grains	Weight per cubic foot saturated air, grains
0	0.80	602.6
5	0.92	595.9
10	1.11	589.4
15	1.32	582.9
20	1.58	576.5
25	1.87	570.2
30	2.21	564.1
35	2.62	558.0
40	3.09	552.0
45	3.64	546.1
50	4.28	540.2
55	5.02	534.4
60	5.87	528.6
65	6.87	525.1
70	8.00	517.7
75	9.80	512.5
80	11.90	507.5
85	14.40	502.7
90	17.40	498.1
95	20.40	493.7
100	24.80	489.5

inside wall surface, and the insulating value of the wall. The difference between the temperature of the inside air and the inside wall surface is to the difference between inside and outside temperature as the reciprocal of K for the inside surface is to the reciprocal of U for the wall.

Let T_i = inside temperature
T_o = outside temperature
T_s = temperature of inside wall surface

Then

$$(T_i - T_s) : (T_i - T_o) :: \frac{1}{K} : \frac{1}{U}$$

or

$$(T_i - T_s) = U \frac{(T_i - T_o)}{K}$$

or

$$T_s = T_i - U \frac{(T_i - T_o)}{K} \qquad (9)$$

To determine the probability of condensation on walls and windows, it is first necessary to find the temperature of the wall surface; then refer to Table 26 to determine the maximum carrying capacity of the air at this temperature. The next step is to find the absolute humidity of the air in the room. If the absolute humidity exceeds the carrying capacity of the air adjacent to the cold wall, there will be condensation on the wall.

Example: In a stable the following conditions existed: the inside temperature was 50°F., and the relative humidity was 80 per cent. Outside temperature was 20°F. The value of U for the barn wall was 0.26, $K = 1.4$; and for the windows $U = 1.13$, $K = 1.5$.

(a) Would there be condensation on the wall? (b) On the window? (c) Would there be frost on the window?

Air at 50°F. and 80 per cent relative humidity carries 3.424 grains of moisture per cubic foot. Substituting in formula (9), we find T_s equal to 44.42°F. The moisture-carrying capacity of air at 44.42°F. is 3.36 grains per cubic foot. Since the air contains only 3.424 grains, there would not be condensation on the walls.

Substituting values for the window glass in the formula, we find T_s to be 27.46°F. The moisture-carrying capacity of air at 27.4°F. is 2.03 grains per cubic foot. Since the inside air carries 3.424 grains per cubic foot there would be condensation on the glass; and since the surface of the glass is 27.4°F. there would be frost. If it were desirable to correct

this condition it might be done by improving the ventilation or by decreasing the value of U for the window or perhaps by some surface treatment, changing the value of K.

It has been stated on good authority that a 50 per cent relative humidity is desirable for the health of people, and no doubt the same holds true for animals. Such a relative humidity causes condensation on the walls and windows in the average home, and to avoid this, decreasing the moisture content of the air is often resorted to. No doubt the better plan would be to use double windows and more thoroughly insulated walls. It would then be possible to have the optimum relative humidity and at the same time avoid undesirable condensation on the walls and windows.

The value of U for double glass is 0.450. Substituting this value, we find the temperature of the inside surface of the glass to be 41°F. Air at this temperature will carry 3.20 grains of moisture per cubic foot. If K remained constant there would still be an excess of moisture that would cause condensation on the glass, but no frost would appear.

In all probability, the storm windows would decrease infiltration and also reduce loss of heat to the point where a higher inside temperature would result, changing T_s for the inside glass. If T_s were increased to 43°F. there would be no condensation.

82. Condensation in Walls.—Just as there is a thermal pressure through a wall from a heated room to the outside cold, so there is a vapor pressure through a wall separating conditions of high relative humidity from low. In a dairy barn having a temperature of 60°F. and 70 per cent relative humidity or in a modern home being maintained at 70°F. and 50 per cent relative humidity, there will be a movement of vapor through the walls. As this vapor moves through the wall at some point within the wall there will be a temperature at which condensation will take place. In walls as commonly constructed, this very often occurs on the inside face of the outer portion. A vapor barrier placed near enough the inside surface to remain above the temperature for condensation is effective in preventing trouble from this source.

Questions and Problems

79. Two cows are equal in size. One is in heavy production, and the other is dry. Which will give off the greater amount of heat? Explain. A farmer made the statement in regard to the effect of cold on small chicks, "My chicks will be all right today even though it is cold, because I gave them a feed of warm mash this morning." Was his reasoning correct?

80. A farmer stated that shutters or doors to close over the windows of his dairy barn on cold nights eliminated his trouble with condensation on windows and walls. Could this be possible? Explain.

81. A water pipe carrying water at a temperature of 48°F. extended through a dairy stable. On two different days the temperature in the stable was 90°F. On one day the pipe was dry, and on the second day water dripped from its surface. Explain, using actual figures.

82. The temperature inside a dairy barn was 40°F. when the outside temperature was 0°F. The relative humidity inside was 65 per cent. The walls were covered inside with yellow pine. The value of U for the wall was 0.265. Would there be condensation on the wall? On the single glass windows? Would double glass windows be desirable?

83. A wall is made up of ½-in. celotex, 4 in. of rock-wool fill, and ¾ in. of yellow pine siding. The temperature inside the wall is 78°F. and outside is −10°F. Secure a sheet of cross-section paper, and draw a temperature curve through the wall. Let 1 in. = 10° on the vertical scale. (Assume that the difference between the surface temperature on the outside of the wall and the outside temperature is the same as the difference between inside temperature and inside wall-surface temperature.)

CHAPTER XVII

VENTILATION

83. Need for Ventilation.—Most students are familiar with the effect of a lack of ventilation on their ability to think and work. Drowsiness is the first evidence, followed by headache. If such conditions were continued indefinitely ill-health would certainly result. If one individual in the group were a disease carrier, the lack of ventilation would make the infection of the others almost certain.

During the first decade of this century the Canadian government was concerned about the spread of tuberculosis in livestock. A leading veterinarian of the time spoke on the subject before the Committee on Agriculture and Colonization, and had the following to say: "Within the reach of every man, and at the least possible cost, there is the best and most effective agent yet discovered for the eradication of tuberculosis. Of infinitely greater value than tuberculin and much more easy of administration, is a plentiful supply of fresh air. If there is one matter today in which veterinarians are behind the age, it is that of failing to insist at all times, in season and out of season, on the importance to livestock of thorough and effective stable ventilation.[1]

The amount of ventilation needed has been determined in past years by three different methods. The first, in order of use, was based on the necessity for a certain standard of air purity in the barn at all times. Professor F. H. King[2] set a standard, allowing not more than 3 per cent of breathed air in the room or stable at any time. This standard was high and required the movement of large quantities of air that resulted in expensive installations and low barn temperatures. To overcome these objections the amount of ventilation was controlled according to the temperature in the barn. When the temperature rose to a certain point a thermostat would start the ventilation system,

[1] Rutherford, Dr. J. C., Veterinary Director General for Canada, 1902–1912.

[2] Deceased; formerly Professor of Agricultural Physics, University of Wisconsin.

and when the temperature had been reduced by the exchange of air the thermostat would automatically stop the system. A third standard for determining the need for ventilation is based on the cooling power of the air. The experiment reported in Chap. XVI indicates that relative humidity and air movement are important factors in the cooling power of the air. Many ventilation systems are designed to provide the circulation needed to remove the accumulated moisture. Power systems are now available with controls that operate according to the relative humidity of the air in the stable or room to be ventilated. As soon as the relative humidity reaches a predetermined point the ventilation system is started and operates until the relative humidity has been lowered to the predetermined limit.

84. Types of Ventilation Systems.—Ventilation systems are divided into two general classes: (*a*) the gravity or natural-draft type and (*b*) the mechanical or forced-draft type. Gravity systems are subdivided into two general classes based on the point from which air is admitted to and removed from the room. (*a*) The King system introduces fresh air at or near the ceiling and removes foul air from a point near the floor, King's theory being that, since carbon dioxide is heavier than air, it will settle to the floor and be the first to be removed. Also, he reasoned that the warm air will rise and will be retained and thus higher stable temperatures will result. (*b*) In the Rutherford system the foul air is removed from the ceiling, and the fresh air is admitted at the floor; or, if greater turbulence is desired, fresh air may be admitted at the ceiling, also (see Fig. 68). The effective height of flue is greater in the Rutherford system, since it is based on the difference in elevation between the fresh-air inlet and the top of the outtake flue. Larger outtake flues are thus needed in the King system to secure the same air change.

The New York single-stack system is of the King type, the essential difference being that all the outlet flues are combined in one large stack or flue. This decreases the cost of installation and will often increase the effectiveness of the ventilation system.

Close observation of air movements in a ventilated stable will at once disclose the fact that air circulation there is the result of the falling of the dense air in the colder parts of the stable and the movement of air along the stable ceiling from the warm parts to the cold parts. There will thus be a general movement from

directly over the rows of cows to the walls and to the pen areas where little heat is generated. A detailed study of the air currents near openings into outtake flues will show that the outgoing movement is noticeable for a surprisingly short distance, certainly less than 6 ft. from the flue opening. This is an important fact. It shows that the location of the outtake flue has a negligible effect on the convection currents of air in the stable, and from this it follows that it is not necessary to have a number of outtake flues in order to ensure uniform stable conditions.

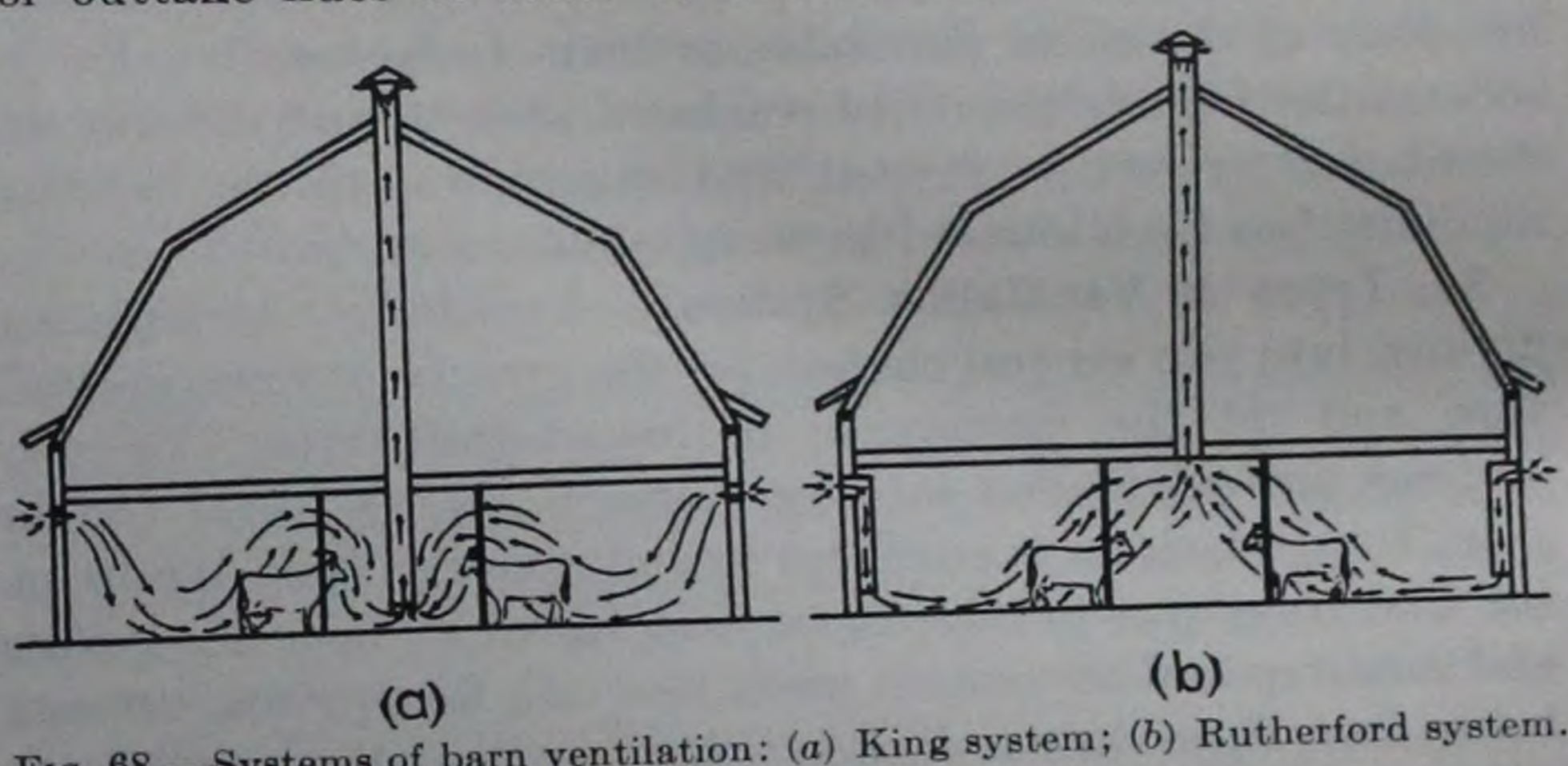


FIG. 68.—Systems of barn ventilation: (*a*) King system; (*b*) Rutherford system.

This means that one large flue may be used for stables of at least 50-cow capacity and probably for more.[1]

This single stack can be located at any point in the barn where it will be out of the way and where it can be constructed with the least number of bends and sloping sections. Uniform conditions must be maintained by proper distribution of fresh-air inlets.

85. Computing Size of Flues.—The size of outtake flue needed will depend on the amount of air to be removed and the velocity at which the air moves in the flue. In the gravity system, the force causing the flow of air in the flue is a result of the difference in weight between the warm, expanded air inside the barn and the cold air outside. The heavier air from outside finds its way into the barn through inlets or through infiltration and forces the lighter air out through the ventilation flue provided. This flue, being insulated, keeps the air warm until it is exhausted at the top of the flue.

[1] RILEY, H. W., Natural Draft Dairy Stable Ventilation, *Agr. Eng. J.*, Vol. 10, No. 4, p. 125, April, 1929.

A warm-air column $H + h$ (Fig. 69) would be required to balance a cold-air column of height H. The additional column h is the amount the two columns are out of balance. The weight of this small, unbalanced column of air supplies the energy to operate the system. The weight of air in the stable and outside, if it is of the same composition, varies as its absolute temperature $(T + 460)$. (The addition of vapor to the inside air would tend to make the air lighter, and the addition of carbon dioxide would tend to make it heavier, resulting in little, if any, change due to these factors.) The relationship of the two columns can be expressed as follows:

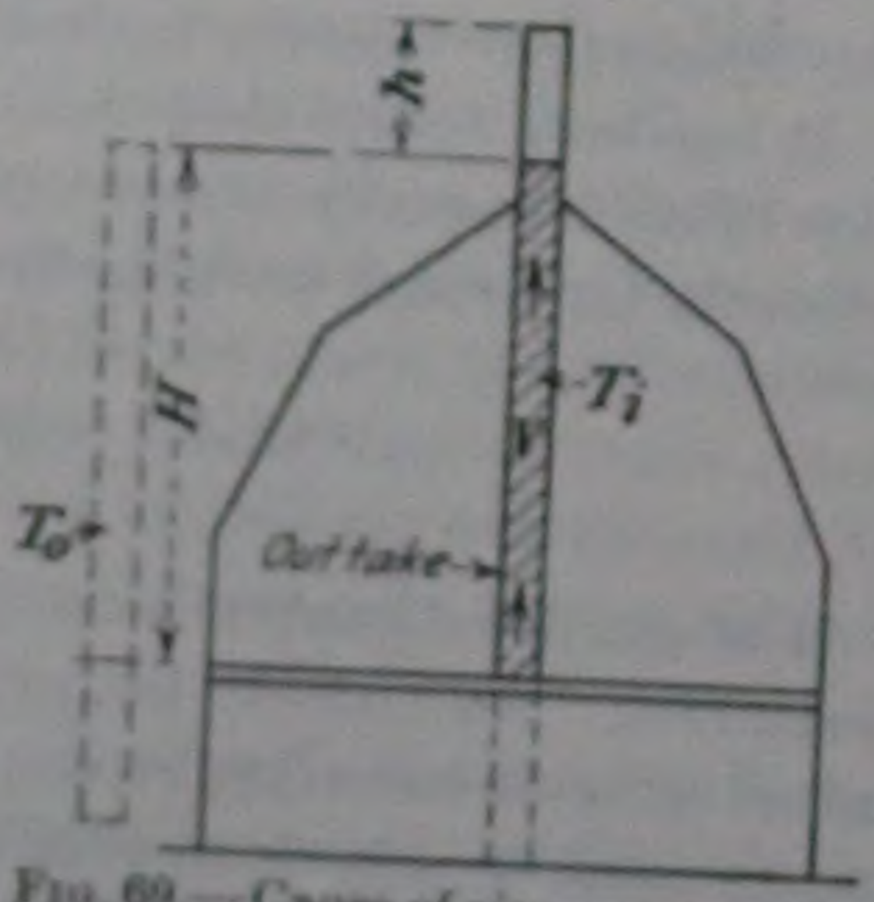


FIG. 69.—Cause of air movement in a flue.

$$H(T_i + 460) = (H + h)(T_o + 460)$$

Transposing,

$$\frac{H(T_i + 460)}{T_o + 460} - H = h$$

Clearing,

$$\frac{H(T_i + 460) - H(T_o + 460)}{T_o + 460} = h$$

Simplifying,

$$h = \frac{H(T_i - T_o)}{T_o + 460} \qquad (10)$$

The velocity of flow is computed by the use of the formula for falling bodies under the influence of gravity.

$$V = \sqrt{2gh} \qquad (11)$$

where V = velocity in feet per second.

g = acceleration of gravity (approximately 32 ft. per second per second).

h = factor corresponding to the height through which the body falls, determined above.

Converting the velocity to feet per hour, removing the constant $2g$ from the radical, and substituting the above value of h,

$$V = 28{,}800\sqrt{\frac{H(T_i - T_o)}{T_o + 460}}, \tag{12}$$

the theoretical velocity in feet per hour.

It has been found that the actual velocity of the air in ventilation flues is usually about 40 per cent of the theoretical. The formula for actual working velocities would then be as follows:

$$V = 11{,}520\sqrt{\frac{H(T_i - T_o)}{T_o + 460}} \tag{13}$$

For quick estimates, a temperature difference of 20°F. is often assumed. An outside temperature of 30°F. produces one of the most difficult tests for the ventilation system. At lower temperatures more energy is available, and at higher temperatures windows may be opened for additional ventilation. If a temperature difference of 20°F. and an outside temperature of 30°F. be assumed, the formula becomes

$$V = 2{,}327\sqrt{H} \tag{14}$$

This gives the velocity of flow under the most trying conditions making for conservative design. When the velocity of flow is known the quantity of air circulated in cubic feet per hour may be found from the formula

$$Q = AV \tag{15}$$

where A = cross-sectional area of flue in square feet.
V = velocity in feet per hour.

If the amount of air circulation needed is known and the velocity in the flue determined, the size of flue may be computed as follows:

$$\text{Area} = \frac{Q(\text{cubic feet of air change per hour})}{V(\text{velocity in feet per hour})} \tag{16}$$

86. Design of Flues for Gravity Systems.—Many ventilating systems are ineffective because of incorrect design of outtake flues. The efficiency of these flues depends on several factors; namely, their effective height, the thoroughness of insulation of the flue, shape of cross section, freedom from bends and horizontal sections, and size—the large flues being somewhat more effective than an equal area in smaller flues. The effective height of a flue is measured from the height at which the cold air enters the system to the point at which the foul-air flue discharges above

the roof. In the King system this would be the difference between the ceiling of the stable and the ventilator head on the roof, and in the Rutherford system it would be the difference between the floor of the stable and the ventilator head.

Outtake flues that carry warm air should be insulated sufficiently so that the value of U for the flue wall is not greater than 0.25. If the air is allowed to cool in the stack the effectiveness is reduced, since the air in the stack would then be more nearly the same weight as an equal column of cold air outside, and if it is allowed to cool in the stack there is almost sure to be condensation on the inside surfaces.

A round flue is ideal because it offers less resistance to flow of air than any other shape. Square flues are next in preference and are often used because of ease of construction. Rectangular flues become less effective as the difference in the length of sides increases. Such flues should be avoided as much as possible.

The vertical flue is the most efficient, and any sections placed more than 30° from the vertical are to be avoided because of the resulting resistance to flow.

87. Fresh-air Inlets.—An inlet, to operate satisfactorily, must admit air at a more or less uniform rate under varying conditions of wind pressure. If intakes are not controlled the amount of air entering the barn will vary with the velocity of the wind. The inlets on the windward side will admit more air as the wind increases in velocity, and those on the leeward side may be back-drafting, that is, allowing air to escape from the stable. This will increase the ventilation to a point at which the barn will be cold. Several companies responding to this need have developed automatic air inlets that admit practically the same volume of air under different wind velocities and also prevent back-drafting (see Fig. 70).

The intensity of stable convection currents is much influenced by the unavoidable chilling effect of the incoming cold fresh air, and therefore the recommendation is made that air intakes should always be located along the outer walls of the stable regardless of whether the cows head in or out.[1] This provides a blanket of cold air next to the wall that may have a tendency to reduce condensation and decrease heat loss.

[1] FAIRBANKS, F. L., and A. M. GOODMAN, Dairy Stable Ventilation, *Cornell Extension Bull.* 151, December, 1926.

With an outside temperature of 30°F. and an inside temperature of 50°F., with all windows closed, because of the difference in density of the inside and outside air, the inlets admitting cold air could have 4 per cent less total area than the outlet exhausting warm air, provided the inlets worked with the same effectiveness as the outlet. This is probably not true, but it seems that the leakage should easily make up for the inefficiency of the large number of inlet openings. Some designers use 10 per cent less area in inlets than in outlets. Since inlets are inexpensive and since resistance in inlets may reduce efficiency, it is believed advisable to make inlets equal in area to outlets, infiltration, of course, being considered.

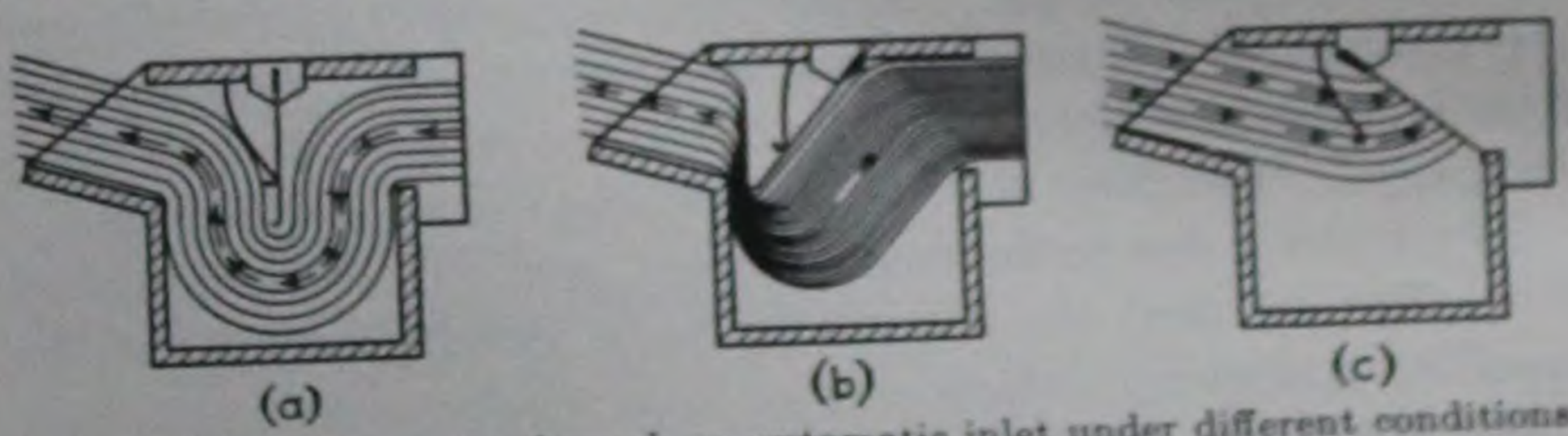


FIG. 70.—Air currents through an automatic inlet under different conditions: (*a*) No wind outside; (*b*) Strong wind outside; (*c*) Stops back-drafting on leeward side.

88. Mechanical-draft Ventilation Systems.—Manufacturers of barn equipment have placed on the market suction fan units for exhausting the foul air from barns or other buildings. These are built in small sizes that may be installed by removing the upper window sash. Suction-fan units may also be secured that are built into a regular cabinet. An opening is made in the wall near the ceiling and the exhaust flue from the fan inserted. Foul air is taken from near the floor or from near the ceiling, as desired. These units may be purchased with either temperature or humidity controls. Table 27 gives data on ventilating fans.

Time and Cost of Operation.—In experiments at Iowa State College, it was found that in a barn housing 35 cows the fan was operating 16.8 hr. each day and required 2.6 kw.-hr. of current per cow per month. The ventilating period extended over about 8 months. During the remaining 4 months the fan was operated intermittently to draw out stable odors and to aid in cooling the building.

TABLE 27.—VENTILATING FANS*

Diameter of fan, inches	Cubic feet air delivered per minute	Revolutions per minute
12	600	1,070
12	900	1,725
16	1,500	1,125
18	2,400	1,150
24	4,300	860

* Courtesy of the Clay Equipment Corporation, Cedar Falls, Iowa.

Questions and Problems

84. Explain the three standards for determining the need for ventilation in a stable. Which one do you think would give better results in practice in Missouri? Which in zone 1? Which is better adapted to automatic control?

85. On a still winter night what path would fresh air take on entering a standard-type dairy barn having a Rutherford ventilating system? A King system? Use sketches to illustrate.

86. A statement has been made to the effect that admitting the cold fresh air over the windows would decrease heat loss through them. Is this correct? Explain. The statement is also made that admitting the cold air along the walls prevents condensation on them. Explain.

87. Why is an outside temperature of 30°F. considered to be a good temperature for testing a ventilation system? Would a system that is adequate at 30°F. outside temperature be more or less adequate at zero, outside temperature? Explain.

88. Eighteen Holstein cows, each producing 40 lb. of milk daily, are housed in a barn on a night when the outside temperature is 30° and the relative humidity outside is 30 per cent. How much air must be changed per hour to maintain a relative humidity of 50 per cent at an inside temperature of 60°F.?

89. If a Rutherford system of ventilation is used and the ventilator head is 36 ft. above the floor of the stable, what size stack would be needed? If a King system were used and the ceiling height of the stable were 8 ft., what size flue would be needed? If this were a one-story dairy barn and the ventilator stack (Rutherford system) was 22 ft. above the floor, what size outtake would be needed? What size and speed of fan would be needed for this installation?

CHAPTER XVIII

HEATING

Heating is the utility most essential for comfort in the farm home. It is therefore the first utility to be planned for and the last to be curtailed in case it is necessary to make reductions in the expenditure. Heating systems in farm homes vary from the wood stove that heats a single room to the automatic oil-burning furnace that heats the entire house. Many low-cost farm homes are built without a basement, and for the most part one or two rooms are heated with stoves. The inside walls are usually not well insulated, making it very difficult to heat these rooms to a comfortable temperature.

89. The circulating heater or jacketed stove utilizes the principle of convection to secure more uniform distribution of heat. As the air in the jacket is heated it expands, reducing its weight per unit volume, and is crowded upward by the heavier cold air coming in from below to take its place. The cool air moves along the floor to the heater, and the warm air moves out from the heater along the ceiling. This system gives much wider distribution of heat than an ordinary stove, but usually will not heat rooms unfavorably located so far as circulation is concerned.

In order to secure more positive delivery of heat throughout the house and to ensure its arrival at any point desired, a modification of the circulating heater has been made. Cold-air return pipes are placed under the floors connecting each room in the house with a central box directly under the circulating heater. The jacket around the heater is closed to the floor to fit over this central connecting box. Louvers to allow the passage of warm air are built into the wall above the doors leading into the rooms to be heated. When the heater is fired the air in the jacket rises, and air is drawn in through the cold-air return system. Warm air flows to the rooms to take the place of the cool air withdrawn. Figure 71 shows the layout of cold-air return pipes. If all registers are left open heat will be distributed

throughout the house. If extra heat is desired in any one room, the registers in other rooms may be closed. The cold-air return system can be made of inexpensive materials so long as there is not too great a loss of air and heat. These return pipes carry air at lower temperature than hot-air pipes in a regular system, and therefore heat losses are not so great. This system gives very satisfactory delivery of heat to points where it is needed

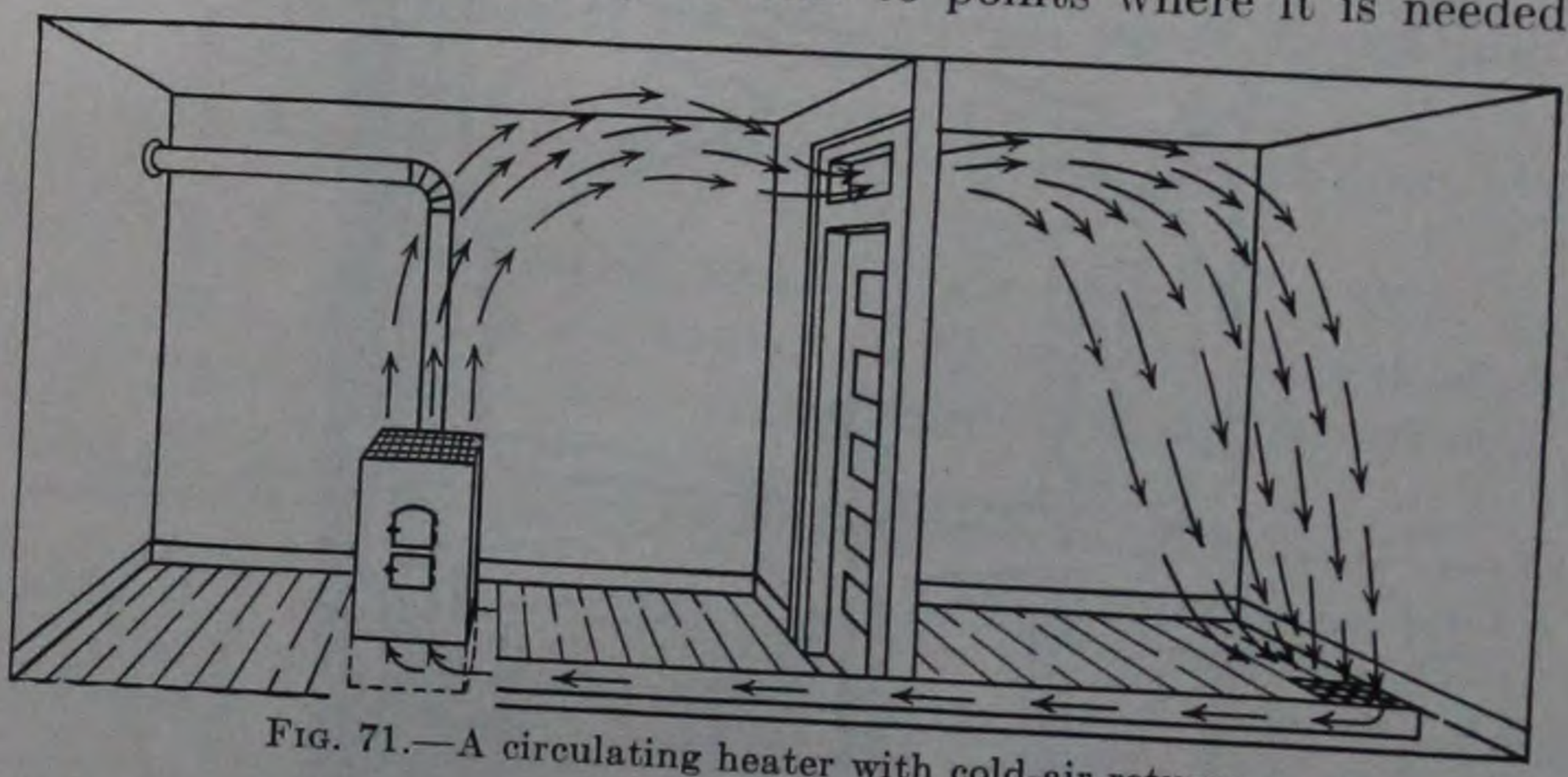


FIG. 71.—A circulating heater with cold-air returns.

and at perhaps the lowest cost of any unit system. To secure the proper size of grate in the circulating heater, use the following formula:

$$G = \frac{1.2 \times 144H}{Efp} \qquad (17)$$

where G = grate area in square inches.
1.2 = correction factor to overcome loss of heat in delivery.
H = total heat requirement of the house.
E = efficiency of the furnace (40 to 60 per cent).
f = fuel value of the coal (Btu per pound, usually 12,000).
p = pounds of coal per hour per square foot of grate (usually 6).

90. A house with a basement permits the use of any of the standard types of heating systems. The *warm-air system* is the one most commonly used (see Fig. 72). It is lower in first cost; it can be shut down without being damaged by freezing temperature; it does not require any special structural design to carry radiators, etc.; and the actual work of installing it is less difficult than for the steam or hot water system. The important points to be considered in planning the warm-air system are (*a*) to secure

the proper size of warm-air pipe for each room and (*b*) to secure a sufficiently large grate area in the fire box to serve the connected heat pipes.

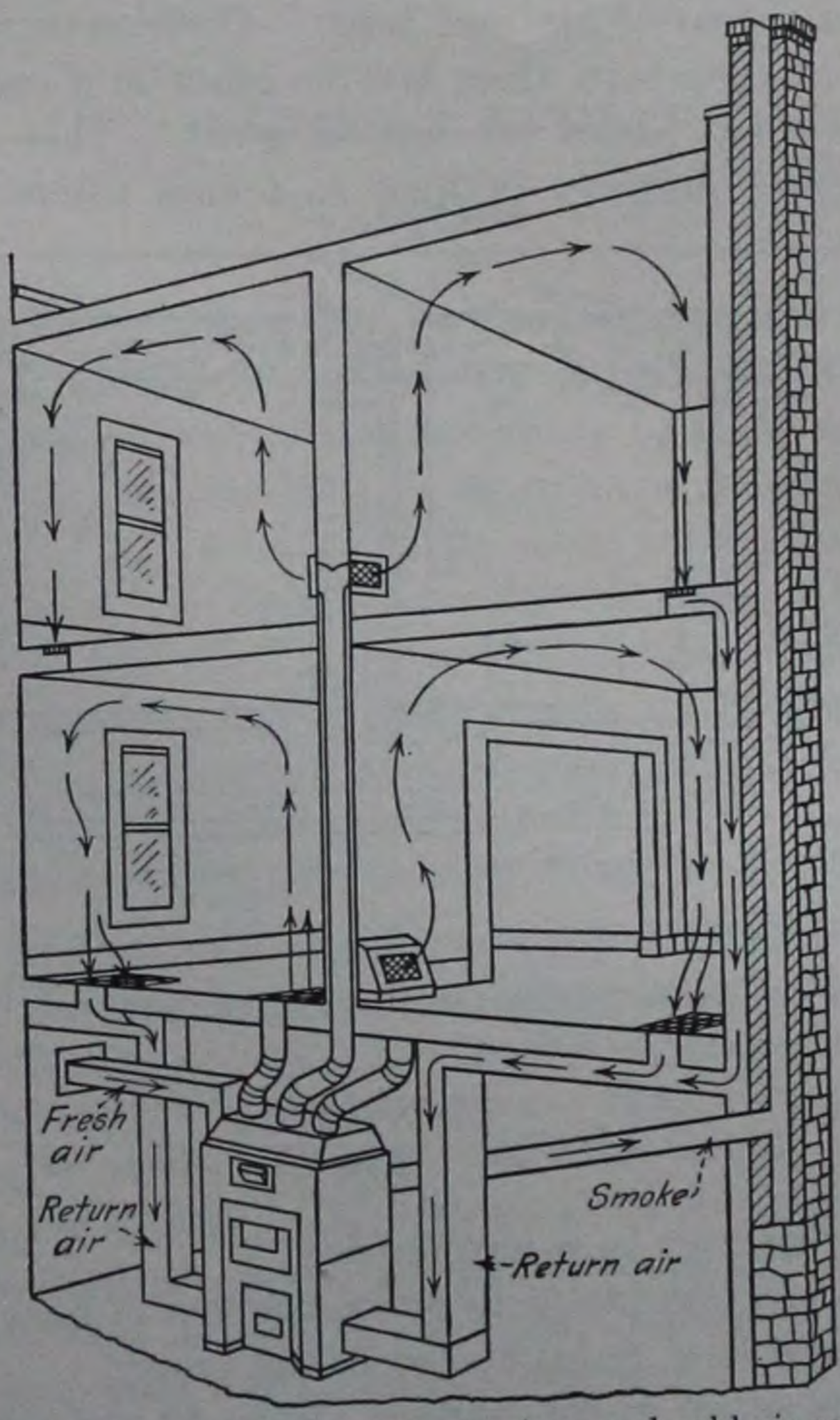


FIG. 72.—Warm-air furnace with warm-air pipes and cold-air returns from each room.

In computing the size of warm-air leaders, a register temperature of 175°F. is assumed. The formulas for computing the size of leaders needed are as follows:[1]

$$\text{First-floor rooms} - A = 0.009H \tag{18}$$

$$\text{Second-floor rooms} - A = 0.006H \tag{19}$$

$$\text{Third-floor rooms} - A = 0.005H \tag{20}$$

where A = the cross-sectional area of the pipe in square inches.
H = the total heat loss from the room in Btu per hour.

[1] "American Society of Heating and Ventilating Engineers' Guide."

The size-of-grate area needed for the furnace may be found by use of the following formula:[1]

$$G = \frac{1.2 \times 144H}{Efp[1 + 0.02(R - 20)]} \qquad (21)$$

where G = grate area in square inches.
E = efficiency of the furnace (from 40 to 60 per cent).
f = fuel values of the coal (Btu per pound, 12,000 average).
p = pounds of coal burned per square foot of grate per hour (6).
R = ratio of heating surface to grate area (20 to 28).
H = total heat requirement of the house in Btu per hour.
1.2 = correction factor to overcome loss of heat in delivery.

TABLE 28.—HEAT EMITTED BY STANDARD-TYPE STEAM RADIATORS*

No. of columns	Height, inches	Rated surface per section	Btu per square feet per hour	
			Intermediate section	End section
1	38	3.00	243	375
1	32	2.50	250	380
1	26	2.00	257	385
1	23	1.66	266	394
1	20	1.50	263	395
2	45	5.00	217	378
2	38	4.00	225	396
2	32	3.33	233	400
2	26	2.66	240	413
2	23	2.33	242	415
2	20	2.00	246	411
3	45	6.00	206	374
3	38	5.00	211	380
3	32	4.50	215	370
3	26	3.75	219	366
3	22	3.00	226	380
3	18	2.25	236	390

* Increase 30 per cent for hot water.

91. In hot-water and steam systems the essential points to be considered are the size of radiators required for each room, the

[1] "American Society of Heating and Ventilating Engineers' Guide."

location of these radiators, and the size of boiler needed to supply the heat. Table 28 gives information that makes it possible to select the proper size of radiator to meet the needs of each room. Steam boilers are rated according to the number of square feet of connected radiation they will serve, and therefore the selection of a boiler is based on the total amount of radiation needed.

92. Electric Heating Systems.—Electricity is used for heating in some localities where the climate is not severe and where electric rates are low. The greatest use of electricity, however, is for supplementary heat in early fall or late spring when the regular heating system is not in operation or during the winter, when additional heat is needed for short periods. The amount of current consumed by this method of heating may be computed by use of the following formula:

$$KWH = \frac{H}{3{,}412} \tag{22}$$

where KWH = kilowatt-hours of current consumed.
H = heat to be supplied in Btu per hour.
The constant 3,412 = the Btu of heat supplied by 1 kw.-hr. of current.

93. The fireplace probably makes its greatest contribution through ventilation and through the added attractiveness furnished the home by an open fire. If it is used carefully, however, it may have considerable value, also, as a supplementary heating unit. The satisfaction secured from a fireplace depends quite largely on its design. If it does not smoke and if it furnishes a comparatively large amount of heat, it will be used a great deal in the average home; however, if it fails in either of these respects its use will be limited and its value discounted. The design of back wall and the relationship between the cross-sectional area of the flue and front opening into the fireplace are the important considerations for securing movement of all of the smoke up the flue. A ratio of 12 to 1 between front opening of the fireplace and cross-sectional opening of the flue has been found to give satisfactory results for one-story houses. A ratio of 15 to 1 has been found to be satisfactory for two-story houses. Too large a ratio between front opening and flue does not permit rapid enough motion of air into the fireplace to prevent smoke from

entering the room. Figure 73 shows a plan for a fireplace. This shows the back wall extending forward to form a narrow flue section extending the full width of the fireplace. The draft created by the flue is spread across the full width of the fireplace opening, tending to prevent the escape of smoke into the room. The sloping back wall extending out over the fire absorbs heat and radiates it out into the room. For long service, this back

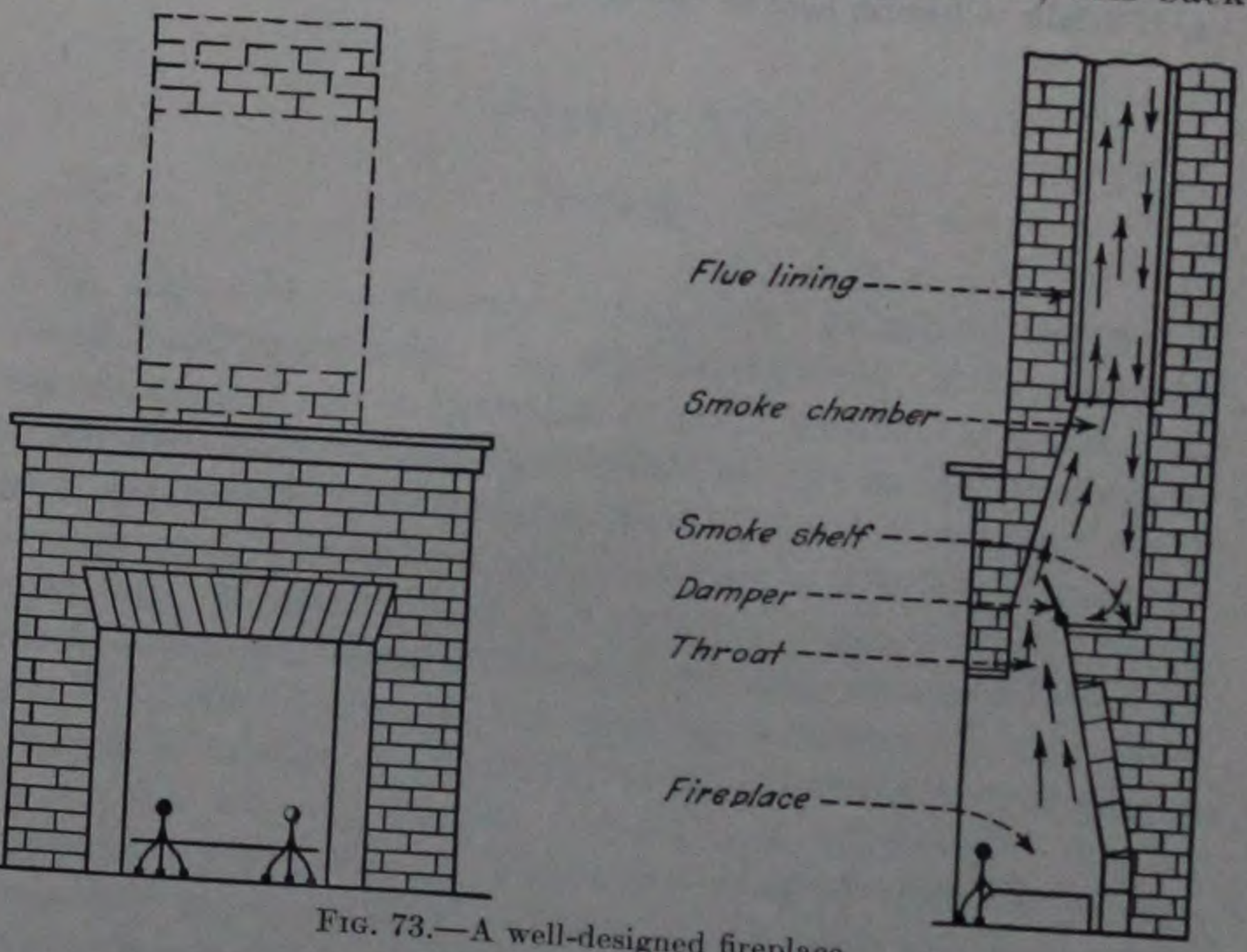


FIG. 73.—A well-designed fireplace.

wall should be made of firebrick laid up in fire-clay mortar. The fireplace depends on radiation alone for transfer of heat. Some special designs to utilize convection currents have added to the value of the fireplace as a heating unit.

Questions and Problems

90. The heat loss from the different rooms in a farm home during a period of the lowest sustained temperature in the area is as follows:

Kitchen	4950 Btu per hour
Living and dining room	6100 Btu per hour
Two bedrooms	4680 Btu per hour each
Bathroom	2100 Btu per hour

a. What grate area would be required in a circulating heater to heat the house?

b. If a standard warm-air furnace is used, what size of leaders should go to each room? (Rooms are all on the first floor.)

c. If a hot-water heating system were used, what size of radiator would be needed in each room?

91. If electricity costs 1.5 cts. per kw.-hr., what would it cost per hour to heat the house?

92. *a.* What are some of the advantages of a fireplace?

b. If a fireplace smokes, what might be the causes?

c. If it fails to furnish heat to the room, what might be the cause?

PART IV

Building Materials

CHAPTER XIX

WOOD

94. Use.—At one time wood could truly be said to be the universal building material. At present, however, other materials are replacing it to a considerable extent. Specifications for some of the large business buildings in cities call for the use of concrete, steel, brick, and other building materials to the complete exclusion of wood. Farm buildings, however, are still built, for the most part, of wood. This is true for several reasons. Wood can be secured in standard sizes at any lumberyard in the country; it is one of the lightest building materials in use, when strength is considered; it can be worked into the desired shapes by anyone who can handle simple tools; it presents a good appearance when properly placed and finished; and it is a comparatively good insulator and can thus be used to aid in maintaining reasonable temperatures within a structure. It has some qualities, however, that do not always meet the demands set up for a building material. Its strength varies widely with the grain fibers and seldom is sufficiently great to allow its use for wide spans or excessive loads. It is subject to knots and other defects requiring high safety factors in design. It is highly inflammable, and for this reason cannot be used where fire risk is a great factor. Its serviceable life may be shortened if it is placed so that fungus growths may attack it readily, and if it is not properly protected from termites it may be destroyed by them. The quality of lumber available is often inferior, and in some cases the cost is high. Although many of these objections can be overcome by the use of glue and laminated, built-up members, the undesirable features of wood in general have led

to the substitution of other materials in various parts of farm buildings.

95. Depreciation.—The so-called "rotting" of wood is caused by a type of fungus that feeds on the wood cells, breaking them down. These fungi develop from spores that are carried by the wind from the fruiting bodies of the parent plant. They come in contact with the wood, and if favorable conditions are present they fasten themselves to the wood and grow, securing their food supply from the cells of the wood. These growths may develop fruiting bodies, or there may be no visible evidence of their presence except the remaining rotted wood. This development can take place only if certain conditions are present, namely, a reasonable amount of moisture, a supply of air, and a favorable temperature. If any one of these conditions is removed the growth of the fungus will be retarded or may not take place at all.

96. Preservation.—Although it is impracticable to eliminate any of these conditions completely in farm buildings, the wood can nevertheless be preserved to some extent by the use of various treatments. Zinc chloride, sodium fluoride, and creosote are the common wood preservatives that work by poisoning the food supply in the wood. Creosote treatments are also effective through waterproofing the wood temporarily until the creosote leaches out. Paint poisons the wood, acts as a waterproofing

TABLE 29.—SERVICEABLE LIFE OF DIFFERENT VARIETIES OF WOOD WHEN USED AS FENCE POSTS

Variety	Years of service without treatment	Variety	Years of service without treatment
White cedar	*	Iron wood	3⅔
Osage orange	*	Hickory	3⅔
Black locust	*	Red oak	3⅓
Catalpa	*	Cottonwood	3⅓
Sassafras	16½	Hackberry	3⅓
White oak	13½	Sugar maple	3⅓
White walnut	11½	Black oak	3
Red bud	10½	River birch	3
Black walnut	9⅓	Dogwood	3
Honey locust	5⅓	Willow	2⅔
Black ash	4⅓	Sycamore	2
White elm	4		

* These varieties are in serviceable condition after 18 years.

agent, and forms a leathery covering, giving considerable mechanical protection from the spores.

Placing the wood away from contact with the ground keeps it dry and thus increases its life. The so-called "dry rot" that affects wood is really not a dry rot at all but a result of fungus growths that send out tendrils to a source of moisture, thus spreading and developing and utilizing the cells of the wood as food, bringing about the resulting decay.

Termites, or white ants, bore into wood and utilize the food supply there to the destruction of the particular part attacked. They must be kept out by mechanical means or by poisoning the food supply (the wood) so that they cannot make use of it.

97. Recommended Use in Construction.—Woods differ in the rate at which the process of decay takes place; therefore, much better service can be secured from a building by a proper selection of wood for different parts. The National Lumber Manufacturers' Association makes the following recommendations for the use of different varieties of wood in a structure:

Light framing	White pine, spruce, hemlock
Heavy framing	Yellow pine, oak
Exterior finish	White pine, poplar, cypress
Interior finish	Redwood, cypress, pine, and any hardwood
Floors	Quarter-sawed oak, maple, hard pine
Doors, sash	White pine, cypress
Sills	Redwood, Oregon fir, cypress, pine
Posts	Cedar, Osage orange, cypress, black locust, catalpa

Where native lumber is to be used, a knowledge of the value of some of the less durable varieties is desirable. Table 29 gives the years of service of several common varieties of wood used as fence posts. Many of these varieties of no value as fence posts will give satisfactory service when kept dry, as in a structure. (The strength of the wood, however, may be a limiting factor in its use.)

98. Classification of Woods. *Hardness.*—The classification of woods according to hardness is based on the premise that all trees that have broad leaves are *hardwoods* and that all that are coniferous are *softwoods*. This is a very poor basis for classification, however, because longleaf yellow pine, for example, is much harder than poplar or willow, although the former is a conifer and the latter has broad leaves.

Growth.—This classification is based on the manner of growth. If the growth is *endogenous*, every point on a tree is pushed upward as growth takes place. The bamboo is a good example of such growth. Most of our native trees are *exogenous*—that is, the growth takes place by adding new growth not only at the top of the trunk but also out from the center, the expansion being in annual concentric layers, the thickness depending on the variety and the conditions for growth.

Use.—This division is made by special selection of materials and by differences in methods of processing. *Finish* lumber is selected for the presence of, or the freedom from, knots, but it is planed or milled to definite sizes and with smooth surfaces; or it may be beaded or shaped into various designs. Finish lumber is selected for appearance; *common* lumber is selected to give service or strength. In each of these divisions we have grades based on quality or condition.

99. Grades of Lumber.—Finish lumber is divided into *A*, *B*, and *C* grades.

Grade A, up to and including 12 in. in width, must show one face practically clear of all defects except that it may have such wane as would dress off if the lumber is surfaced on four sides.

Grade B will admit of one split end where the depth of split does not exceed the width of piece, small seasoning checks that do not show an opening through, a limited number of sound knots, and 1-in. wane.

Grade C will admit any of the above defects that will not materially affect its strength or usefulness when the lumber is placed.

Common lumber is graded No. 1, No. 2, No. 3, and No. 4.

Number 1 *common* boards or strips, rough or dressed on one or two sides, must be suitable for use without waste and will admit the following defects or their equivalent: a limited number of sound knots, checks, and holes well scattered; machine defects that will not cause waste; pitch pockets; shake that does not go through the piece; and wane not to exceed 1 in. in width and ½ in. in depth and one-third the length of the piece.

Number 2 *common* boards or strips, rough or dressed on one or two sides, will admit the following defects or their equivalent: medium knots, worm holes, machine defects that will not cause waste; pitch pockets; through shakes that do not exceed one-half the length of the piece; splits that do not exceed one-fourth the

length of the piece; streaks of advanced decay not to exceed ½ in. in width by one-fourth the length of the piece; wane 2 in. wide by one-half the length of the piece. Miscut or machine-damaged 1-in. common lumber that does not fall below ¾ in. in thickness will be accepted as No. 2 common, provided the grade of such stock is otherwise as good as No. 1 common.

Number 3 common boards and strips, rough or dressed on one or two sides, will admit coarse knots, loose or decayed knots and knotholes, through checks, shakes and splits, serious defects in dressing, pitch, pith, advanced decay, stain, wane, or other defects that will not prevent its use as a whole for cheap sheathing or that will cut 75 per cent of lumber as good as No. 2 common.

Number 4 common boards and strips include all pieces that fall below the grade of No. 3 common, excluding such pieces, however, as will not be held in place by nailing after wasting one-fourth of the piece by cutting into two or three pieces. In the division into grades it is necessary to recognize and define the different defects in wood that will put it into one of these classes.

100. Defects in Wood (American Lumber Standards).—*Checks* are lengthwise separations of the wood that occur across the rings or annual growth. These may be surface or through checks, as the term indicates.

Decay is a disintegration of the wood substance, caused by action of wood-destroying fungi. The words *dote* and *rot* are synonymous with the term *decay*.

Holes may be from any cause and may extend partly or entirely through the piece. Holes are measured by their maximum diameter. Pin, medium, or large worm holes vary from less than 1/16 to ¼ in., respectively.

Imperfect manufacture includes all defects that are produced in manufacture, such as chipped grain, loosened grain, raised grain, torn grain, skips in dressing, machine burn, machine gouge, mismatching, miscut, insufficient tongue and groove, etc.

Knots are classified according to size, form, and quality. Sizes under ½ in. are called pin knots; from ½ to ¾ in., small knots; from ¾ to 1½ in., standard knots; and over 1½ in., large knots. A *spike knot* is one that is sawed through lengthwise. A *sound knot* is one that is solid across its face and that is as solid as the surrounding wood.

Pitch pockets are openings between the grain of the wood containing more or less pitch or bark and are classified as small, standard, medium, and large.

Shakes are cracks either intersecting or parallel with the annular rings, resulting, usually, from excessive strains caused by wind storms, ice, sleet storms, or improper felling of trees.

Stain is a discoloration of lumber resulting in any color other than the natural color of the piece.

Wane is bark, a lack of bark, or a decrease of wood from any cause on the edge or corner of a piece.

Warp is any variation from a true or plane surface. It includes crook, cup, or any combination thereof.

Questions and Problems

93. What are the different classes of wood from the standpoint of (*a*) growth; (*b*) varieties of wood; (*c*) use?

94. How could inferior methods of logging affect the (*a*) quality of lumber? (*b*) careless work in the mill? (*c*) lack of care in the yards?

95. What are the common wood preservations? Why are they not more extensively used?

96. (*a*) What are termites? (*b*) How may their presence be recognized? (*c*) What can be done to prevent them from damaging a building?

Reference

Snyder, Thomas E.: "Control of Termites in Buildings," *Agr. Eng. J.*, Vol. 9, No. 8, p. 240, August, 1928.

CHAPTER XX

WOOD FASTENERS

101. Nails.—Most of the joints in farm structures are fastened with nails or spikes. There are several kinds of nails made especially for different conditions. Common nails are of two kinds—wire and cut. In addition to these, finish, case, shingle, lath, box, and church nails are in common use. The size of nails is expressed by the term *penny* (represented by the letter d, as

TABLE 30.—LENGTH AND WEIGHT OF NAILS

Description		Cut nails, number per pound		Wire nails, number per pound					
Size	Length, inches	Common	Finish	Common	Fence	Spikes	Case	Finish	Shingle
2d	1	740	1,100	876	...	..	1010	1351	
3d	1¼	460	880	568	...	..	635	807	429
4d	1½	280	530	316	...	..	473	584	
6d	2	160	300	181	124	..	236	309	
8d	2½	88	168	106	82	..	145	189	
10d	3	60	104	69	50	41	94	121	
12d	3¼	46	96	63	40	38	87	113	
16d	3½	33	86	49	30	30	71	90	
20d	4	23	76	31	23	23	52	62	
30d	4½	16	.....	24	...	17	46		
40d	5	12	.....	18	...	13	35		
50d	5½	10	.....	14	...	10			
60d	6	8	.....	11	...	9			

10d, etc.), which has come down from the time when nails were made by hand. An 8-penny nail was of such size that 100 nails could be sold for 8 pennies; a larger nail cost 10 pennies, etc. Tables 30 and 31 give information on nails.

102. Nailed Joints.—The holding power of a nailed joint depends on several factors that may or may not be easily meas-

ured or evaluated. The variety of wood, its seasoning, size of nails, quality of workmanship, coating, number used, and the manner in which the load is applied all have an effect on the strength of the nailed joint.

TABLE 31.—QUANTITY OF NAILS REQUIRED

Unit of construction	Size of nail	Pounds required
1,000 shingles	3d	4
1,000 lath	3d fine	7
1,000 ft. b. m. beveled siding	6d	18
1,000 ft. b. m. sheathing	8d or 10d	20 or 25
1,000 ft. b. m. flooring	8d or 10d case	30 or 40
1,000 ft. b. m. studding, etc	16d and 20d	15 plus 5

The U.S. Department of Agriculture "Wood Handbook," prepared by the Forest Products Laboratory, Madison, Wis., gives the following formula for the holding power of nails when the load is applied at right angles to the nail.

$$P_n = KD^{3/2} \tag{23}$$

where P_n = safe load in pounds per nail assuming a factor of safety of 6 for softwoods and of 11 for hardwoods.
K = a constant varying with the variety of wood.
D = diameter of nail in inches.

For values of K to be used in this formula, see Table 32. For convenience in using this formula, the values of $D^{3/2}$ for the different sizes of nails are given in Table 33. This formula is based on a depth of penetration into the block receiving the point of from not less than one-half the length of the nail (for dense hardwoods) to two-thirds the length of the nail (for softwoods).

Example: A 2 by 6 yellow pine joist is fastened to a 2 by 6 yellow pine stud with four 16d nails. What would be the holding power of this nailed joint? The load would be applied at right angles to the nails, and therefore the formula $P_n = KD^{3/2}$ would apply. Referring to Table 32, we find the value of K for shortleaf yellow pine to be 1,120. From Table 33 we find the value of $D^{3/2}$ for 16d nails to be 0.0652. Substituting these values in the formula, we find the safe load for one nail to be $P_n = 1{,}120 \times 0.0652$, or 73 lb. Multiplying this by 4 (the number of nails), we find the safe load of the joint to be 292 lb.

TABLE 32.—VALUES OF K FOR FORMULA $P_n = KD^{3/2}$

Kind of Material	Values for K
Longleaf yellow pine	1,580
Shortleaf yellow pine	1,120
Cedar (Western red)	900
White pine	900
Elm	1,010
Hemlock (Eastern)	1,010
Hickory	1,700
Oak (white)	1,350
Cypress	1,220
Douglas fir	1,010
Maple (silver)	1,010
Tamarack	1,220

TABLE 33.—VALUES FOR $D^{3/2}$ FOR USE IN THE FORMULA FOR COMPUTING THE HOLDING POWER OF NAILS

Size of Nail	$D^{3/2}$
4d	0.0311
6d	0.0380
8d	0.0474
10d	0.0570
12d	0.0570
16d	0.0652
20d	0.0841
30d	0.0942
40d	0.1068
60d	0.1349

103. Spacing of Nails in the Joint.—Some carpenters follow a rule to space nails no closer together than one-third their length and no closer to the edge of the stock than one-fourth their length. The spacing will, of course, depend a great deal on the material. If the material does not split easily more nails can be used than the rule specifies. Several tests have shown, in fact, that the strength of nailed joints may be increased 50 per cent by the addition of 50 per cent more nails than called for in the rule. The rule calls for more nails, however, than are used in common practice.

104. Effect of Clinching on the Holding Power of Nails.—Tests were made on 400 nailed joints,[1] with nails of sufficient length to extend through the piece. Properly clinched joints showed an

[1] WOOLEY, J. C., The Holding Power of Nailed Joints, *Agr. Eng. J.*, Vol. 20, No. 10, pp. 385, 386, October, 1939. Tests made by Xain McNeal, graduate student, University of Missouri, 1937–1938.

increase of over 50 per cent when compared to unclinched joints made with the nails extending through. By selecting nails having the proper length to remain embedded in the piece without showing through, a joint can be made that will hold slightly more than one made with longer nails of the same diameter driven through the piece. No test data are available, however, for this difference. It seems that a 30 per cent increase in strength for a properly clinched nailed joint over one made with the short nails would be a conservative estimate.

In the tests mentioned, four sets of joints were made with the use of uniform stock, size, and number of nails. On one set the nails were clinched with the line of pull on the piece on which the clinching was done; in another set the nails were clinched across the grain at a right angle to the line of pull; in the third group the nails were clinched against the line of pull on the piece on which the clinching was done; and in the fourth set the nails were driven through and left without being clinched. The holding power of the joints decreased in the order of the groups mentioned.

An example in practical construction work will be helpful. It is general practice to nail the joists to the studding, and if this is done the nails should be bent up on the studding side. Perhaps the best practice would be to drive two nails through the joist near the end and close to the outside of the stud. These should be bent up on the side of the stud. The remaining nails for the joint should be driven through the stud and the joist and bent down on the side of the joist. Clinching nails across the grain in the line of pull would give maximum results.

105. Bolts.—Carriage and stove bolts are commonly used in woodwork. Carriage bolts have a square shank with a round head exposed. Stove bolts may be secured in round or flat heads cut for the use of a screw driver.

106. Bolted Joints.—The framework in modern buildings is made up of 2-in. members, as a rule, and most joints are combinations of these materials. The holding power of a bolt depends on the strength of the wood, the size of the bolt, the area of contact with the wood, and the design of the joint in which it is used.

The following formula may be used to compute the holding power of a bolt.

$$P_b = KAR \tag{24}$$

where P_b = safe load of bolt in pounds.
K = constant varying with the wood (same as for P_n, see Table 32).
A = projected area of wood in square inches in contact with bolt (length of bolt in the wood × diameter of bolt in inches).
R = ratio of length to diameter of bolt in contact with the wood (piece with least thickness).

The values derived by use of the formula $P_b = KAR$ must be modified for different design of joints. If R in the foregoing formula is less than 4, no change is required in P_b. If R falls between 4 and 8, P_b must be reduced 50 per cent. If R is over 8,

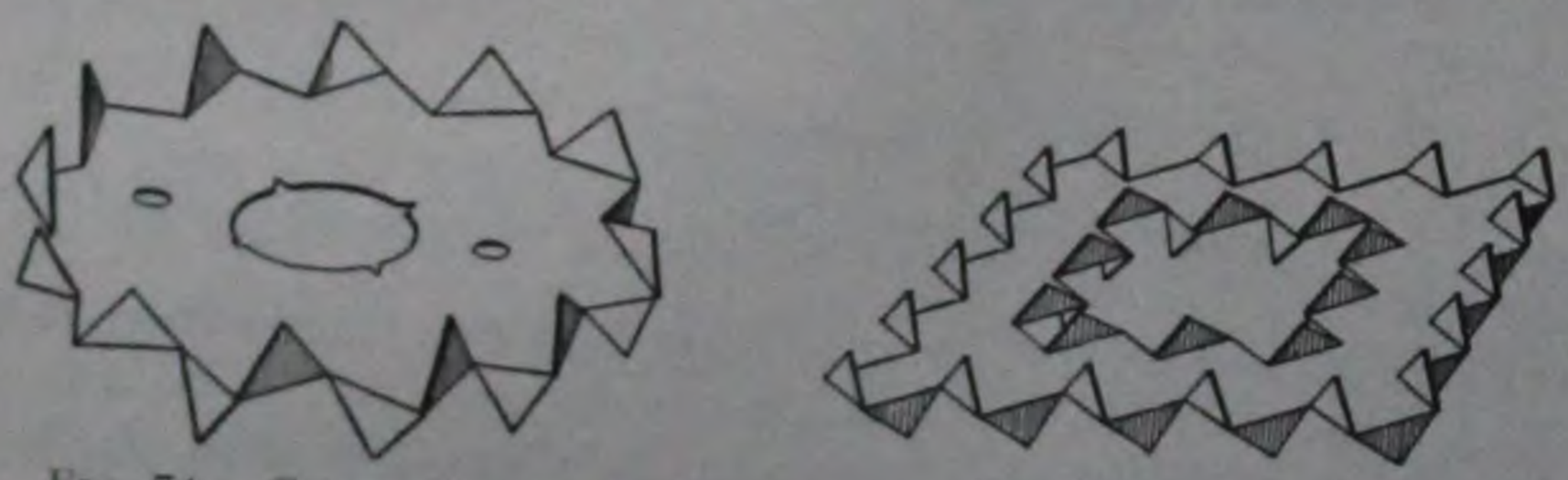


FIG. 74.—Connectors for strengthening splices in wood members.

the value of P_b must be reduced 66 per cent. In case of a common lap joint with pull on one end of a bolt, the value of P_b computed to meet the requirements for R must be reduced 50 per cent.

107. Spacing of Bolts in a Joint.—The spacing should not be closer than 4 times the diameter of the bolt and not closer to the edge of the stock than 1½ times the diameter of the bolt. The holes for bolts should not decrease the cross-sectional area more than 25 per cent.

108. Special connectors used in combination with bolts will increase the holding power of a bolt from 100 to 200 per cent, depending on the type of connector used and the quality of workmanship applied in installing it (see Fig. 74 for illustration of connectors).

Questions and Problems

97. A joist of yellow pine 2 by 12 in. is nailed to a 2- by 6-in. yellow-pine studding by use of five 16d spikes. The spikes are driven through the joists into the studding. What would be the safe load for the joint? If a 2- by 6-in. block has been nailed against the studding immediately below the

joist, using three 16d nails, what would have been the safe load? Could the same number of nails have been used to secure greater holding power?

If the joint is made using $3\frac{3}{8}$-in. bolts, how much would it hold?

If special connections were used with perfect workmanship, what would it hold?

98. The bill of material for a building calls for the following material.

2,300 ft. b.m. of dimension lumber
1,400 ft. b.m. barn siding
2,330 ft. b.m. tongue-and-groove flooring
21,000 wood shingles

Make a list of the nails that will be needed for the job.

99. Two 1- by 6-in. pieces are nailed together using 6d nails spaced according to the rule for spacing and clinched to secure maximum holding power. How many nails could be used and how much weight would the joint hold?

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"Wood Handbook," Forest Products Laboratory, Madison, Wis.

CHAPTER XXI

CONCRETE

CEMENT

109. Concrete is a product made by mixing cement and water paste with an inert material known as an *aggregate*. In describing a mix, the parts of cement and parts of aggregate are usually expressed in the manner 1–3, indicating that 1 cu. ft. of cement is used to 3 cu. ft. of aggregate. Concrete is designed to meet any or all of the following requirements: strength, durability, resistance to wear, and waterproofness.

110. Portland cement is one of the most carefully made manufactured products. A very small percentage of the failures in concrete work can be traced to the cement factory. In the manufacture of Portland cement, lime rock must be quarried and crushed to the fineness of ordinary flour. It is then mixed with a definite amount of clay. Then the mixture is subjected to a temperature of from 2500 to 3000°F. or until the two materials fuse together and go into chemical combination. This product is called *clinker* and resembles the clinker produced in burning coal. The clinker is allowed to weather or cool for a stated period, after which it is returned to the mill and a small percentage of gypsum added. This mixture is ground and put in sacks holding approximately 1 cu. ft. (94 lb.) and is then ready for shipment.

The presence of water will cause these materials to go through another chemical change, resulting in the setting or hardening of the cement; consequently it is necessary to keep the cement perfectly dry until it is to be used. It is not safe to store cement on the ground or on a concrete floor even for a short period of time, for it will come in contact with capillary moisture from the ground and its quality will be impaired. It should be stored under a good roof and so piled that air can circulate under and around it at all time.

111. Aggregates.—The term *aggregate* applies to the sand, gravel, rock, cinders, or other materials that are mixed with the

cement to form concrete. The use of a carefully prepared cement with poor aggregates is a waste that should be avoided, for an inferior quality of concrete is sure to result.

112. Qualities of a Good Aggregate.—First, it must be clean—that is, reasonably free from organic and vegetable matter, silt, or clay. The presence of silt or clay in aggregate used for making concrete will result in an inferior product. The clay in such a mixture is brought to the surface in troweling, and the resulting surface will show wear and become rough and pitted, thus decreasing its usefulness.

Aggregates should be *sharp*, which is only another way of saying that they should be of good quality. Sand that is sharp will be coarse and of good quality, or it would have been worn smooth in the process of erosion. Shale must be avoided, for it will not furnish a bond for the cement; nor will it provide the strength needed in concrete. Concrete will be very little stronger than the aggregates from which it is made.

The third requirement is that the aggregates shall be *variable in size*. If the materials meet this requirement they can be packed more closely and thus will form a more dense mixture. Fewer voids will be found in the resulting concrete, and it will thus be of better quality. It is, of course, necessary that clean water (sufficiently clean for drinking) be used.

113. The Silt Test.—A test for determining the amount of silt or clay in an aggregate can be made in a short time with very inexpensive equipment. This test will not give absolutely accurate results but will give a close enough check for all practical purposes. The test is made as follows: Take an ordinary quart fruit jar. Place in this jar 4 in. of the sand or gravel to be tested. Add water until the depth of sand and water together is 6 in. Screw the lid on the jar, and shake the jar until the clay and silt have been washed off the sand particles. (This usually requires about 1 min. of shaking.) Place the jar on a level surface, and allow it to stand about an hour, or until the silt has settled out of the water. If you find over $\frac{1}{8}$ in. of silt settled on top of the sand or gravel the aggregate will not be fit to use in reinforced work, such as posts, tanks, or silos, or in walks or floors where a troweled surface is desired, unless the silt is first washed out (see Fig. 75).

A plant for washing gravel is rather expensive and not practical on the average farm. One method that can be used to get rid of

some of the silt and clay is to wash the gravel while it is on the wagon or truck. Apply water to the top of the load with a hose or bucket, letting it wash through the sand, and drain off at the bottom of the wagon or truck bed. Apply water until it runs out of the bottom of the load in a fairly clean condition. Shoveling the material as the water is applied will aid the work. Where sand or gravel can be piled to allow a season's rains to wash through it a much improved product is obtained.

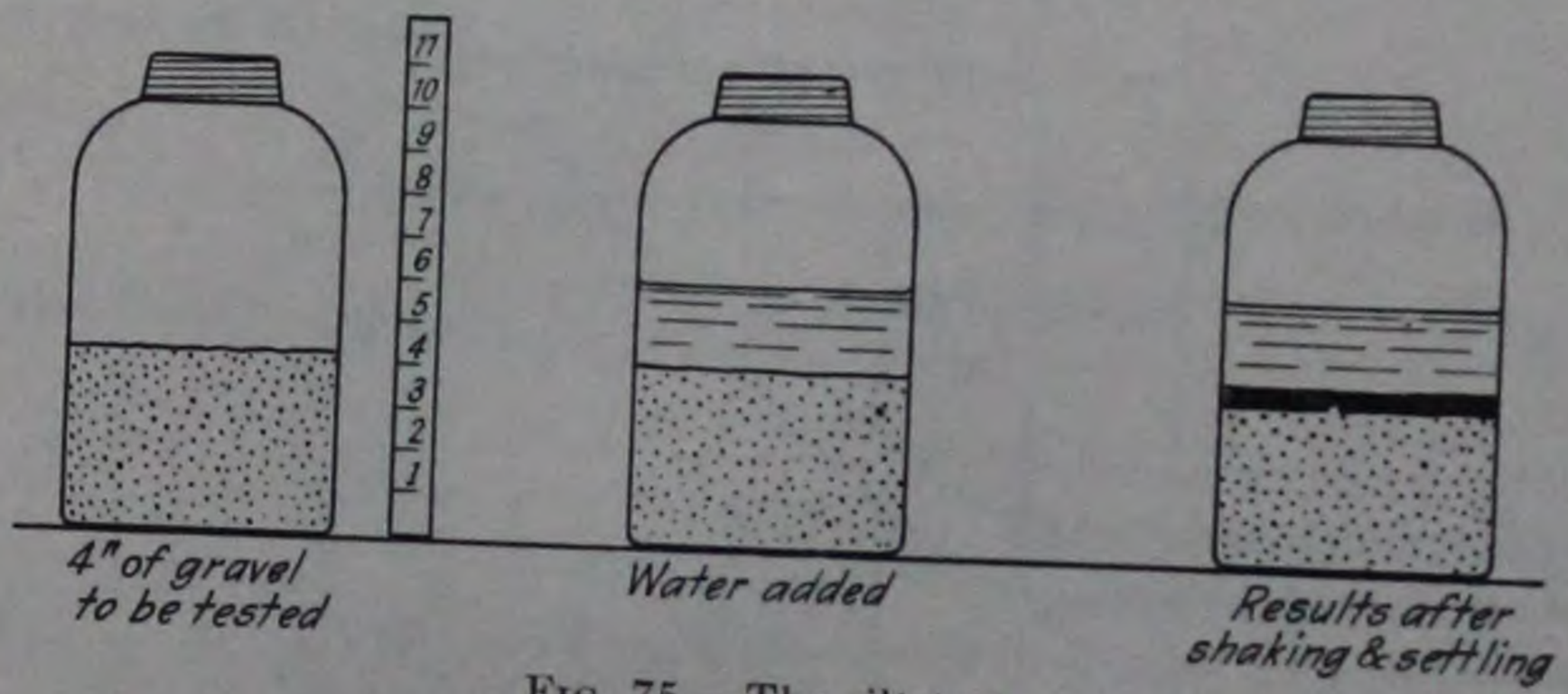

FIG. 75.—The silt test.

114. Amount of Water to Use in Concrete.—It is only within recent years that those making concrete structures have appreciated the importance of having the correct amount of water in the mix. Too much water decreases the strength of the concrete just as effectively as leaving out a part of the cement. After years of testing and observation, the *water-cement ratio law* has been developed and proved. The law reads as follows: For given materials and conditions of handling, the strength of concrete is determined solely by the ratio of water to cement so long as the mixture remains plastic and workable. Different grades of concrete require different ratios of water to cement. The greater the proportion of water to cement the greater the quantity of sand and pebbles that can be used with each sack of cement and, of course, the less the strength of the resulting concrete. Table 34 gives the proper amounts of water to use for different classes of farm work. It will be seen from this table that the amount of water used per sack of cement should be reduced considerably where wet aggregates are used over the amount of water used per sack of cement with dry aggregates.

After a trial batch has been mixed it may be found that the mix can be cheapened by adding more sand or pebbles or both. So long as the mixture remains plastic and workable the maximum

amounts of these aggregates should be used. A mix must be workable before it will go into the forms and make dense concrete. *Caution:* Water *must not* be added unless cement is added at the same time. The water-cement ratio is fixed and must *not* be changed. After the correct proportion between the cement paste, the sand, and the gravel is determined, a measuring

TABLE 34.—RECOMMENDED MIXTURES FOR TRIAL BATCH*

Kind of work	Gallons of water to add to each one-sack batch			Trial mix for first trial batch		
	Wet sand	Average sand	Dry sand	Cement	Sand	Pebbles
Footings and foundations below ground, retaining walls, etc	4¾	5½	7	1	3	5
Watertight basement walls, manure pits, silos, dipping vats, cellar walls, feeding floors	4¼	5	6	1	2½	4
Water tanks, septic tanks, cisterns, driveways, posts, chimney caps, etc	3¾	4	5	1	2	3

* Adapted from Permanent Farm Construction, Portland Cement Association *Bulletin*.

box will be found to be a timesaver. The box should be made large enough to hold the pebbles used in one batch. The depth of sand needed can be worked out and the box filled to this point for each batch. Where a power mixer is used the proper proportion of cement, sand, and rock may be secured by counting the shovels of each needed to obtain the quantities desired in the mix.

It is shown in Fig. 70 that the strength of concrete varies from 1,800 lb. per square inch, where 8 gal. of water are used per sack, to 5,000 lb. per square inch, where 4 gal. of water are used per sack.

ESTIMATING QUANTITIES OF MATERIAL

In estimating the quantities of material needed in concrete work, one of three methods may be employed, depending

on the kind of aggregate used and the accuracy needed in the estimate.

115. Where a single aggregate is used (*a*) the *cubic feet* of space inside the forms is first ascertained. (*b*) If a lean mix is used the amount of aggregate needed is determined by adding 5 per cent to the volume determined in (*a*). A lean mix is one in which there is more aggregate than is used in the 1-3 mix. If a 1-3 mix is used the cubic feet of space found in (*a*) will be sufficient. (*c*) To

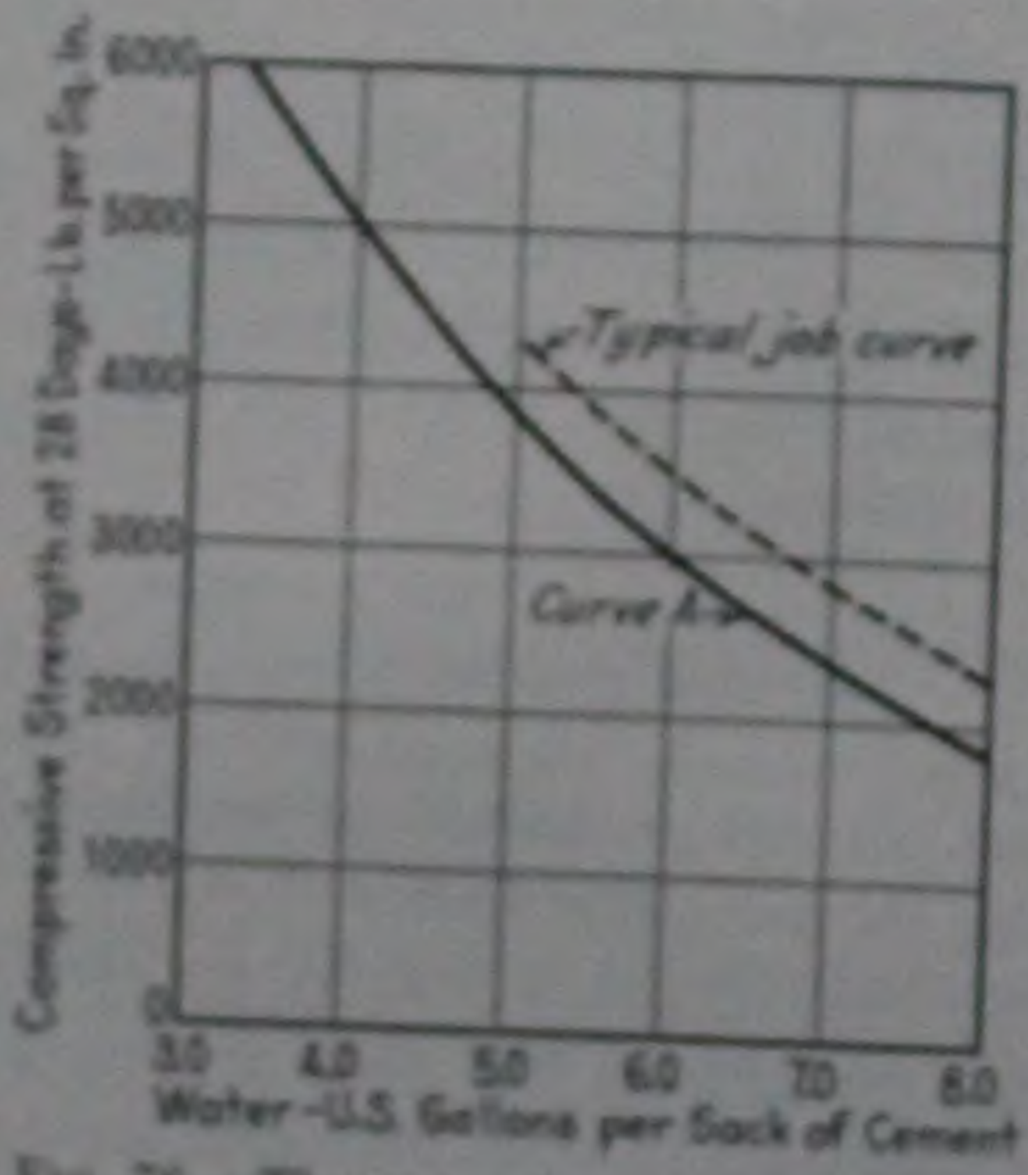

FIG. 76.—The water-cement ratio curve.

find the amount of cement needed, the cubic feet of aggregate needed is multiplied by a fraction whose numerator is the proportion of cement and whose denominator is the proportion of the aggregate in the mix. This will give cubic feet or sacks of cement required for the job.

116. Where fine and coarse aggregates are separated use Fuller's rule:

$$C = \frac{42}{c + s + r} \qquad S = \frac{C \times s}{27} \qquad R = \frac{C \times r}{27} \qquad (25)$$

where C = sacks of cement per cubic yard of concrete.
c = proportion of cement in the mix.
s = proportion of sand in the mix.
r = proportion of rock in the mix.
S = cubic yards of sand per cubic yard of concrete.
R = cubic yards of rock per cubic yard of concrete.

After determining the sacks of cement, cubic yards of sand, and cubic yards of rock per cubic yard of concrete, the total amount of each may be computed.

117. Absolute volume method is an accurate method for estimating quantities to be used on large jobs where the size of the undertaking will warrant the extra computations involved. The quantities of materials in a concrete mixture may be determined accurately by making use of the fact that the volume of concrete produced by any combination of materials, so long as the concrete is plastic, is equal to the sum of the absolute volume of the cement plus the absolute volume of the aggregate plus the volume of water.[1] The absolute volume of a loose material is the actual total volume of solid matter in all the particles. This can be computed from the weight per unit volume and the specific gravity as follows:

$$\text{Absolute volume} = \frac{\text{unit weight}}{\text{specific gravity} \times \text{unit weight of water}} \quad (26)$$

in which the unit weight is based on surface dry aggregate. Water weighs 62½ lb. per cubic foot.

The method can best be illustrated by an example. Suppose the concrete batch consists of one sack of cement (94 lb.), 2.2 cu. ft. of dry fine aggregate (110 lb. per cubic foot), and 3.6 cu. ft. of dry coarse aggregate (100 lb. per cubic foot) and is to be mixed with a water-cement ratio of 7 gal. per sack. The specific gravity of the cement is usually about 3.1 and of the more common aggregates, about 2.65. The volume of concrete produced by the foregoing mix is calculated as follows:

$$\text{Cement} = 1 \text{ cu. ft.} \left(\frac{94}{3.1 \times 62.5}\right) = 0.49 \text{ cu. ft.}$$
absolute volume

$$\text{Fine aggregate} = 2.2 \text{ cu. ft.} \left(\frac{110}{2.65 \times 62.5}\right) = 1.46 \text{ cu. ft.}$$
absolute volume

$$\text{Coarse aggregate} = 3.6 \text{ cu. ft.} \left(\frac{100}{2.65 \times 62.5}\right) = 2.18 \text{ cu. ft.}$$
absolute volume

[1] "Design and Control of Concrete Mixtures," p. 18, Portland Cement Association, Chicago, Ill.

$$\text{Volume of water} = \frac{7.0^*}{7.5} = 0.93 \text{ cu. ft.}$$

$$\text{Total volume of concrete produced} = \frac{\text{absolute volume}}{5.06 \text{ cu. ft.}}$$

Thus one sack of cement produces 5.06 cu. ft. of concrete, neglecting absorption or losses in manipulation. The cement required for 1 cu. yd. of concrete is, therefore, $\frac{27}{5.06} = 5.34$ sacks or 1.33 barrels. The quantities of fine and coarse aggregate required can be found from a simple computation based on the number of cubic feet used with each sack of cement; thus, for the fine aggregate $\frac{5.34 \times 2.2}{27} = 0.44$ cu. yd. and for the coarse aggregate $\frac{5.34 \times 3.6}{27} = 0.71$ cu. yd.

Questions and Problems

100. (*a*) A certain job calls for 6 gal. of water per sack of cement. By what percentage would the durability of the concrete be decreased by using 8 gal. of water per sack of cement instead?

(*b*) What percentage of the cement was wasted by the addition of the extra water in problem 100(*a*) if no aggregates were added?

101. (*a*) What is the yield of concrete per sack of cement with a 5 gal.-per-sack water-cement ratio when dry sand and crushed limestone are used?

(*b*) With a 7-gal.-per-sack ratio?

102. What will be the cost of a concrete fence post 6½ ft. long, 4 by 4 in. at the top, and 6 by 6 in. at the bottom? A 1-2-3 mix is used, four reinforcing rods at 3½ cts. each, and the labor cost is 25 per cent of the material cost.

103. A 20 by 20-ft. Missouri-type poultry house is to have a concrete foundation and floor. The foundation is 4 in. wide and 2 ft. 6 in. high and is placed on a footing 6 in. deep and 12 in. wide. The 2-in. concrete floor is placed on a 4-in. rock fill. Specify the mix for each part, and figure cement, sand, and rock needed for the job.

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CHAPTER XXII

CONSTRUCTION IN CONCRETE

The fact that good materials were used in the proper proportion does not ensure high-quality concrete. There is still a definite procedure to be followed in order to get good results.

118. Mixing Concrete.—The strength, durability, and wearing quality of concrete may be increased by proper mixing. Figure 77 shows the results of tests in which concrete was mixed 20 sec.,

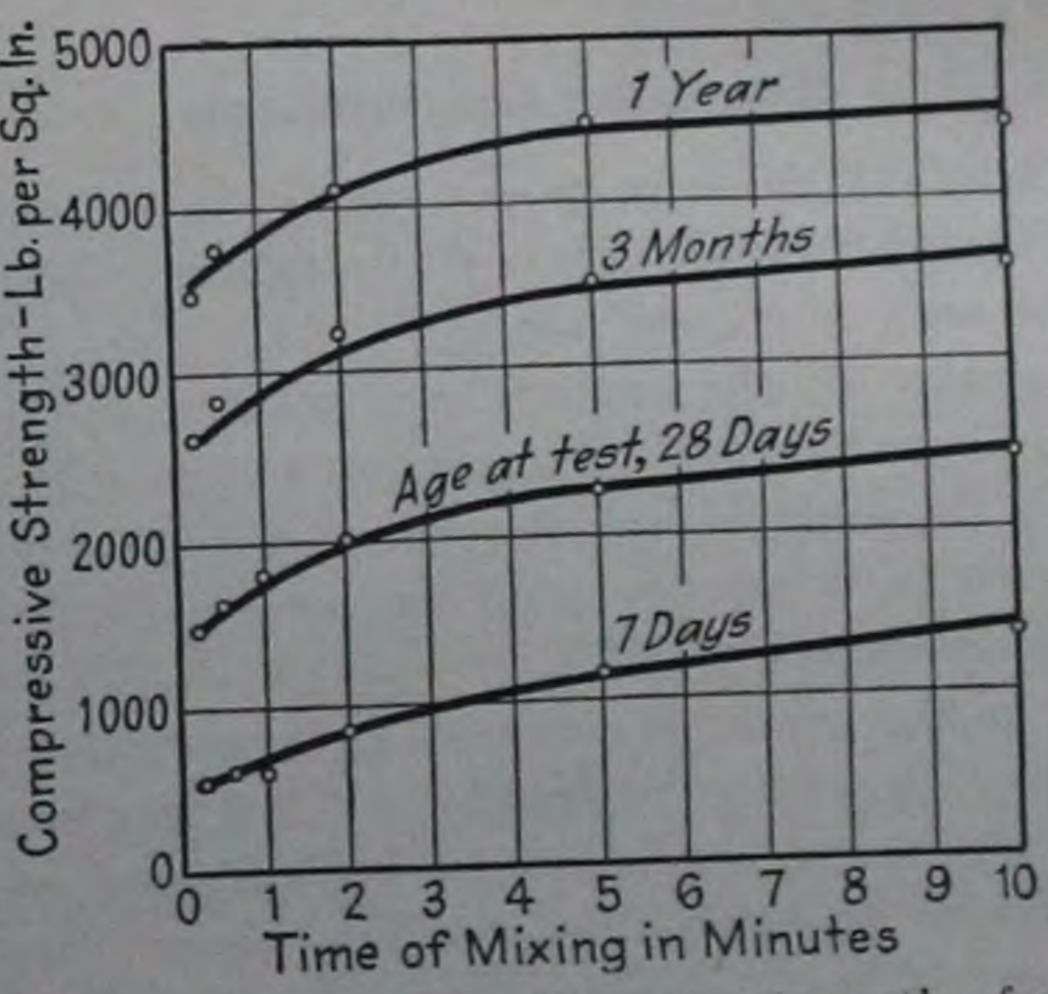

FIG. 77.—Effect of time of mixing on strength of concrete.

40 sec., 1, 2, 5, and 10 min. It is evident that the strength of the concrete increases as the time of mixing increases, up to 5 min. After that amount of time in the mixer, little additional strength is secured by additional mixing. Increase in strength is rapid up to 2 min., and for most work the additional quality secured will pay for leaving the materials in for this length of time.

Some precautions must be taken in placing concrete in order to secure best results. Forms should be wet thoroughly or oiled to prevent too much absorption of moisture from the concrete. The material should be placed as soon as possible after mixing,

45 min. being the absolute maximum allowable time. The material should be placed in even layers in the form and should be spaded or tamped only enough to eliminate air pockets. Excessive spading may cause lamination. A rough surface on top of the concrete is desirable if work is stopped for any considerable length of time. The roughened surface can be treated with neat cement when work is resumed in order to secure a bond between new and old concrete.

119. Surfacing Concrete.—Many times the form marks make a concrete foundation unsightly, thus detracting from the appearance of the building. In warm weather the forms can be removed in from 8 to 10 hr., and in cold weather, in 24 hr., at which time all form marks may be rubbed off with a soft brick or a flat piece of concrete. The surface should then be given a brush coat of 1-2 cement and the sand mixed to the consistency of cream. In walks and floors it is usually desirable to have a uniform surface that will stand up under wear. This may be a floated or a troweled surface. The slabs should be marked off and the edger used while the concrete is green. The material should set until it becomes reasonably firm. The surface is then floated with a wooden trowel or float; a short, circular motion is used until the surface is covered with a sticky paste of cement and sand. Floating also serves to remove high spots and fill the low, leaving a more nearly perfect plane. The floated finish may be left as it is, or the surface may be troweled if desired. After the surface has been finished, the marker and edger should again be used to straighten up the edges. The work should be covered to prevent too rapid drying out. The purpose of floating and troweling concrete is to secure a uniform surface and to bring a rich coating of cement to the surface to provide a good wearing cover.

120. Curing Concrete.—Two conditions are necessary for the proper setting of concrete: the presence of moisture and a favorable temperature at the time the work is done. The chemical changes that take place require the presence of moisture, and if it is not supplied the action will be only partly completed and the concrete will have only a proportional strength. A covering of moist earth or straw will prevent rapid evaporation and drying out. This covering should be kept wet for a period of 1 week at least. An earth dam may be built around the edge of the floor

or walk and the concrete flooded with water. This practice is often followed in concrete road construction.

Figure 78 shows the effect of keeping concrete moist while it is curing. From this graph we see that concrete that is allowed to dry out as soon as it is placed has a compressive strength of 1,400 lb. per square inch. Ten days in damp sand almost doubled the strength of the concrete, indicating the importance of proper care after placing.

The rate of setting is dependent on the temperature, which must always be kept above freezing. In placing concrete during cold weather, the aggregates and water should be heated and the

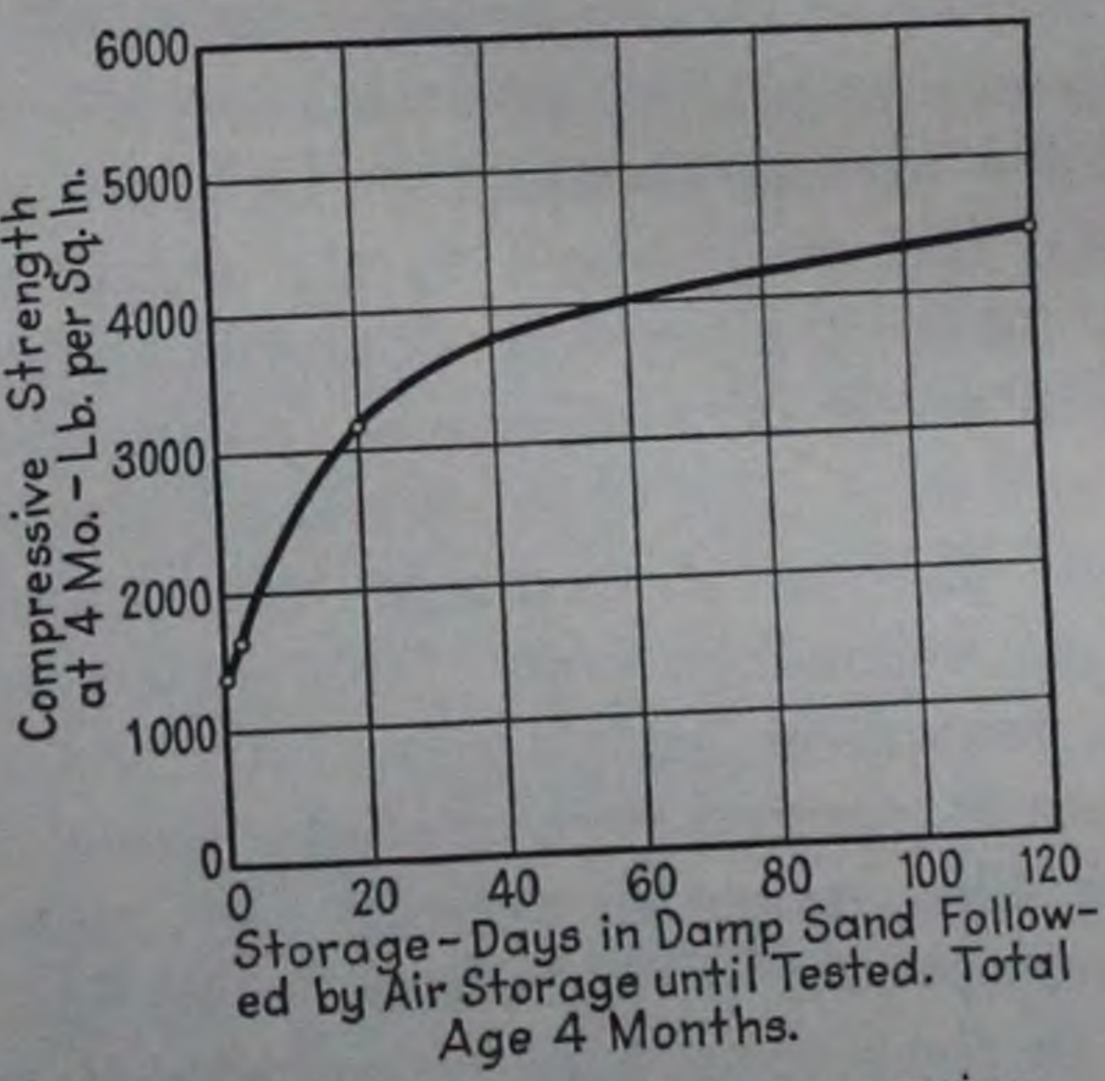

FIG. 78.—Effect of moisture on curing.

concrete covered to hold this heat while it is setting. For ordinary work, however, it is better to avoid cold weather, since there is danger in cold weather of securing a poor product.

Figure 79 shows the effect of temperature on curing of concrete. Setting or curing of concrete is a chemical action and, like other chemical actions, is increased by an increase in temperature. A much higher grade of concrete work is secured on the average if it is done during the summer season.

121. Reinforcing Concrete.—Steel expands and contracts at practically the same rate as concrete when the temperature is changed; therefore, steel may be embedded in concrete to increase its strength in tension. In a beam placed and loaded as shown in Fig. 80, there is a tendency to pull the particles apart on the bottom and an equal tendency to press them together in the top

half of the beam. Concrete is only one-tenth as strong in tension as it is in compression, and consequently the beam would fail by pulling apart near the center on the lower side.

If the proper amount of steel is embedded in the concrete near the lower edge, it would be possible to add ten times the first

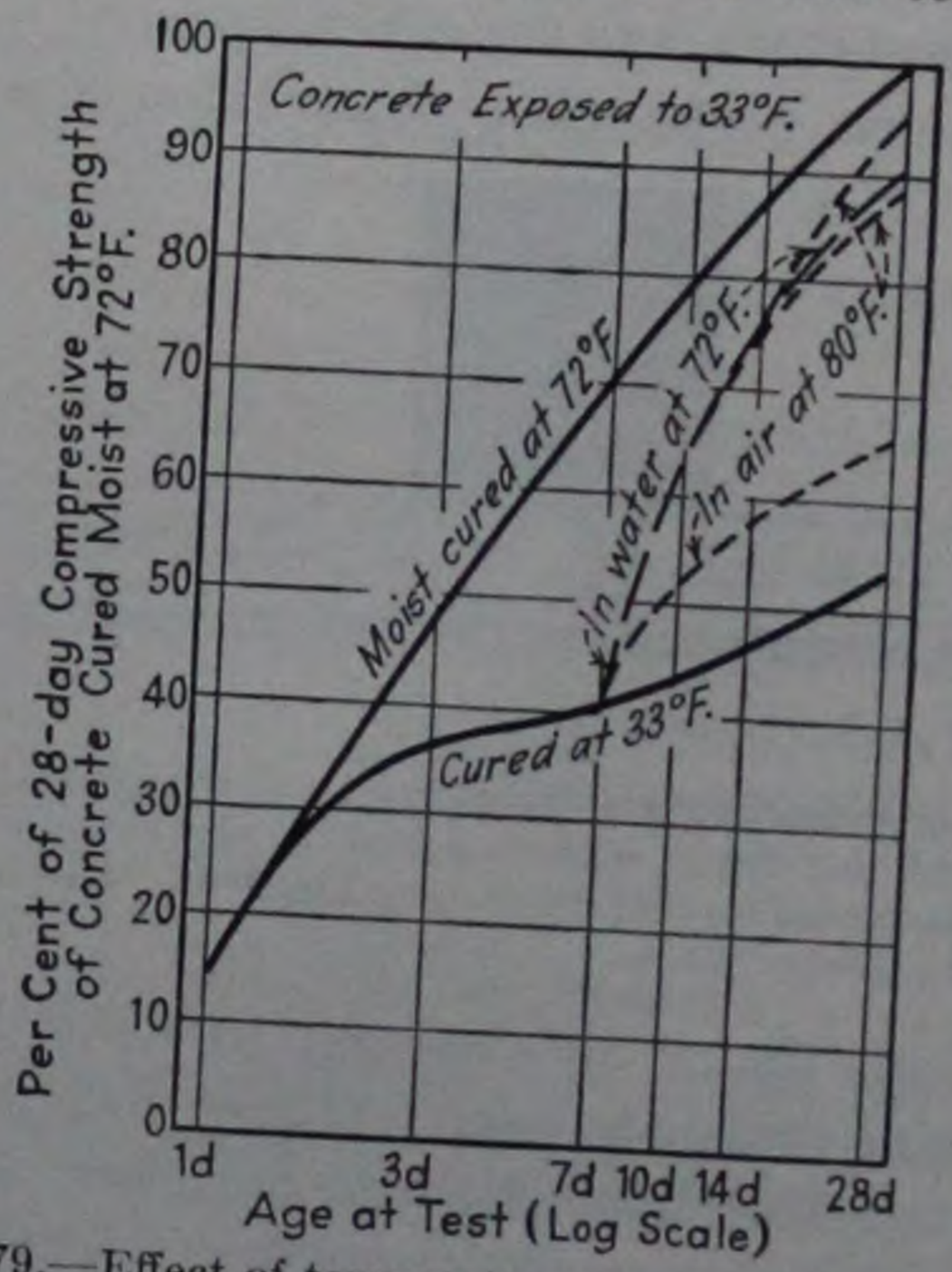

FIG. 79.—Effect of temperature on curing of concrete.

load or more to the beam before it would fail (see Fig. 81). The best rule to follow in placing reinforcement is to place the steel where the tension will come. In a concrete post the strain may come from any side, and consequently the reinforcement is placed at the corners (see Fig. 82). This reinforcement should

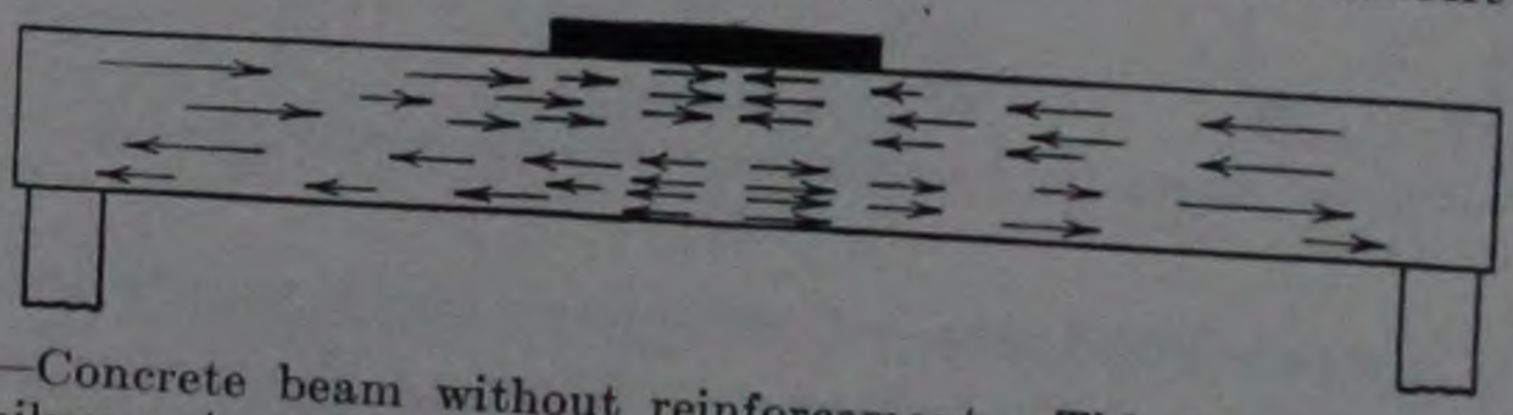

FIG. 80.—Concrete beam without reinforcement. This beam was loaded to failure. A concentrated load of 60 lb. was required to break it.

be as close to the outside as possible and still give a good bond between the steel and concrete. Also, it is necessary to have a concrete covering over the steel to prevent weathering.

Water tanks must be reinforced to prevent the concrete from breaking when the water in the tank freezes.

122. Kinds of Reinforcing.—A heavy grade of hog wire has been used with more or less success for reinforcing feeding floors, tanks, and silos; but regular reinforcing steel is much better material to use. Wire is not good reinforcing material because wire will stretch when a strain is applied. This allows the concrete to crack, admitting moisture, and the wire soon rusts. This is especially true in concrete posts. It is the opinion of men who have

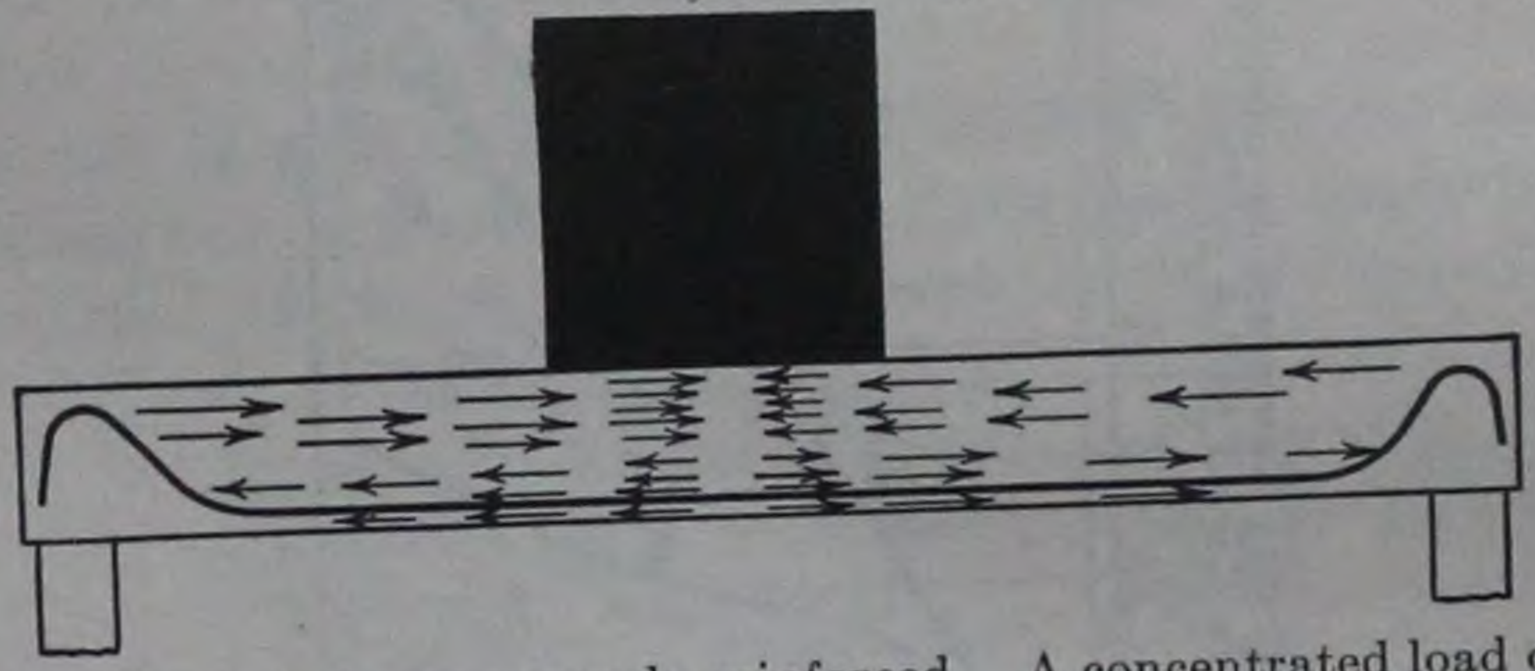

FIG. 81.—Concrete beam properly reinforced. A concentrated load of 890 lb. was required to break this beam, while a beam the same size, but not reinforced, failed under a concentrated load of 60 lb. (see Fig. 80). This shows the value of reinforcement in the proper place.

used concrete posts that it does not pay to make them unless the regular reinforcing rods are used. These rods are made with rough surfaces to secure bond with the concrete, and they have a high carbon content to prevent stretching. This reinforcement is quite expensive but the additional cost is justified by long service. This material can be secured from any wholesale hardware company in any length desired.

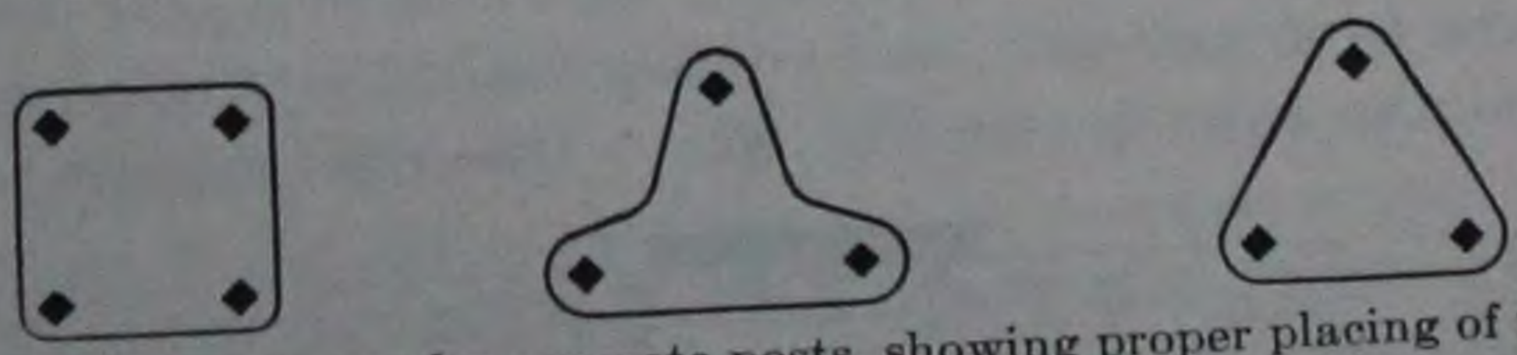

FIG. 82.—Popular shapes for concrete posts, showing proper placing of reinforcement.

123. Concrete Products.—Concrete products plants are located in many sections of the country. Most of these plants manufacture concrete blocks, concrete brick, concrete staves for silos and bins, and precast concrete joists to be used in residence or in barn construction. The concrete blocks are usually made in two standard sizes, 5 by 8 by 12 in. and 8 by 8 by 16 in. Half blocks and corner blocks are made to go with these sizes to facilitate construction. A product known as a *cinder block* is

made in some plants. Cinder blocks are made from cement and screened cinders, mixed in the proportion of 1 part of cement to 7 parts of cinders. They are light in weight and have excellent insulating value. Nails can be driven into the blocks for fastening casings, baseboards, etc. They are recommended for use in one-story houses, and, if of good quality, they may be used under conditions necessitating heavier loading.

Concrete bricks are made in standard sizes, and, if of good quality, they can be used at any point where clay brick would be suitable.

Precast concrete joists are usually designed for 16-in. spacing, the size and the amount of reinforcing depending upon the length of the joist. Unless beams of greater strength are ordered especially, they are designed for a loading of 150 lb. per square foot of floor supported. These joists may have a much more extensive use in the future in sections where termites are creating a problem.

Questions and Problems

104. (*a*) Assuming that the durability of concrete varies as its strength, what percentage could be added to the serviceable life of concrete by leaving it in the mixer 2 min. instead of the average 40 sec.?

(*b*) What change in water-cement ratio would be necessary to secure the same increase in strength?

105. Explain the difference in strength between the beam shown in Fig. 80 and the one shown in Fig. 81.

106. In a rectangular water tank where should the horizontal reinforcing be placed? The vertical reinforcing?

CHAPTER XXIII

COBBLESTONE, CONCRETE, AND CLAY PRODUCTS

124. Cobblestone.—In many parts of the country field stone of good quality may be secured for building construction. Structures built of such material are permanent, the maintenance cost is low, the first cost is usually less than for other types of construction, and no great amount of skill is required in laying the stone into a satisfactory wall. Many farmers in Missouri have built milkhouses, poultry houses, roadside markets, barns, and even dwellings with only a little help in starting the work.

125. Selecting Stone.—The more durable the stone the better the wall that can be built from them. The rough, igneous rock found in glaciated regions may be used; and where colored rocks are available they can be worked into pleasing effects. Weathered limestone, granite, and even flint rock make excellent cobblestone walls. The rocks should be clean and should be of such size that at least one dimension will not be greater than the width of the wall desired. Rocks that are too large can be broken with a sledge.

126. Foundations.—The cobblestone wall is usually heavier than an ordinary wall and requires extra width of footing. This is usually provided for by widening the foundation trench at the bottom. It is also important to extend the foundation below frost line in order to prevent heaving and cracking of walls. A barn footing should be 2 ft. wide. Small residences generally have a footing 18 in. wide. Footings 12 in. wide will serve to support icehouses, milkhouses, and poultry houses. Care must be taken to get the foundation trench true to form and especially to give it a flat bottom. This provides maximum load-bearing capacity. In building the foundation and footing, rock is mixed with the concrete. If this procedure is properly followed, a good foundation may be built at a reasonable cost. A common mistake is to fill the trench part full of rock and pour a slushy mix of concrete over it. This results in a weak foundation sup-

ported on points of rock. Better construction is to start with a layer of concrete mixed to a medium or mushy consistency placed on the bottom of the trench. Put in a layer of rock, then more concrete. In this way a solid mass of high strength is secured, and at the same time a large amount of rock is used. To lay a cobblestone wall, a form for the inside of the wall should be built as shown in Fig. 83 and then a row of stones laid in a

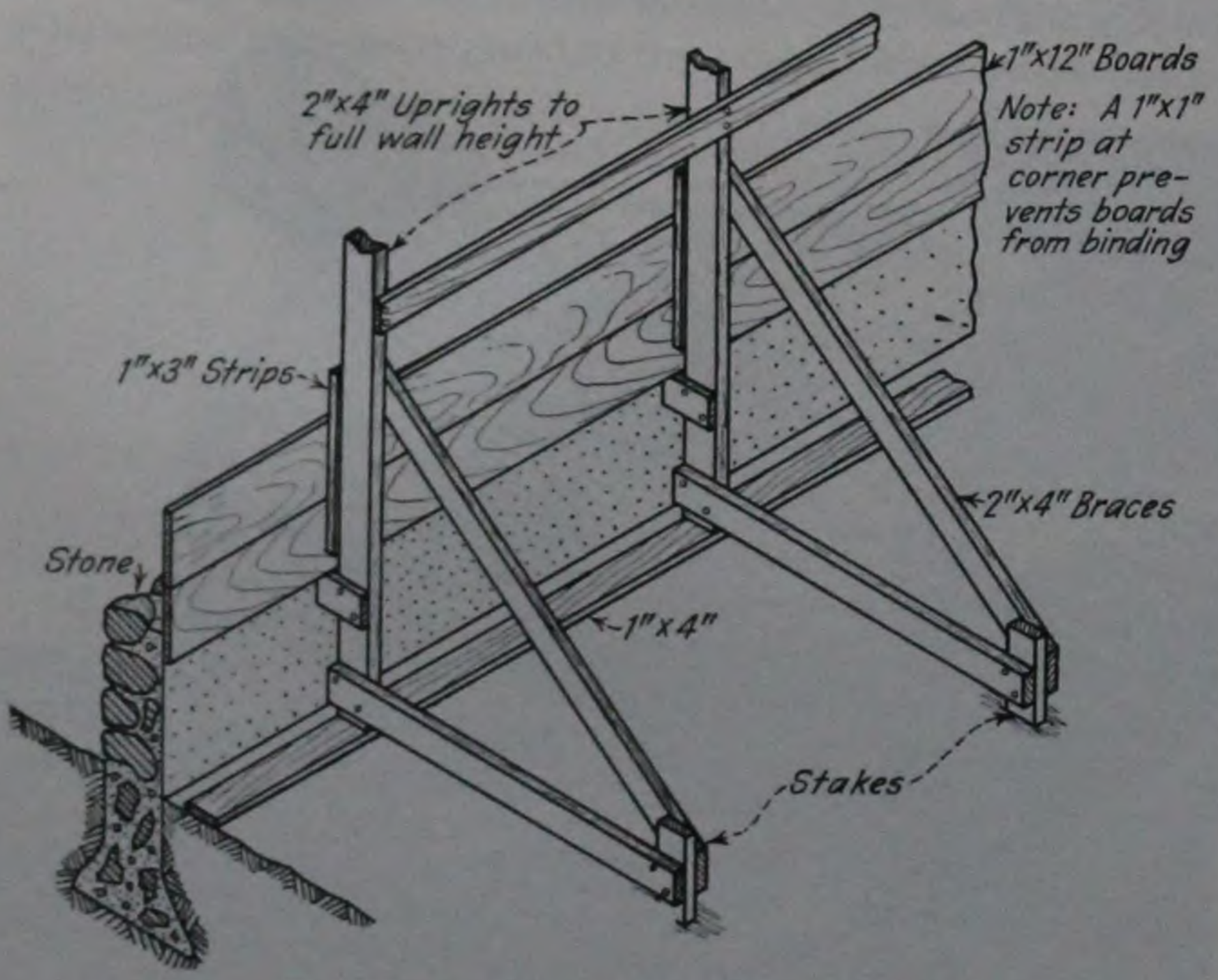

FIG. 83.—Form for cobblestone wall.

mortar bed for the outside form. The concrete filler is then poured between the inside form and the stones. In placing stones, be sure to break joints to secure a tie, and avoid, as much as possible, the effect of horizontal layers.

In case it is desired to insulate a cobblestone wall, the best practice is to attach furring strips to the inside surface and then lath and plaster or fasten wallboards or other interior covering to these furring strips. The furring strips may be nailed to small wooden blocks placed in the walls at the time of construction. This provides an air space between the wall and the interior covering. This air space is a good insulator and prevents condensation of moisture on the inside walls (see Fig. 84).

127. Reinforcing.—Reinforcing rods should be built into the wall at the corners and at other points where the wall will be subjected to bending action. Window lintels and the space over door frames need reinforcing, the amount and kind depending on the loads to be carried and the type of frames used.

128. The Concrete Filler.—The mixture suggested for use in laying up the cobblestone wall is 1 part cement, 2½ parts sand, and 2½ parts gravel. This mixture, with enough water added

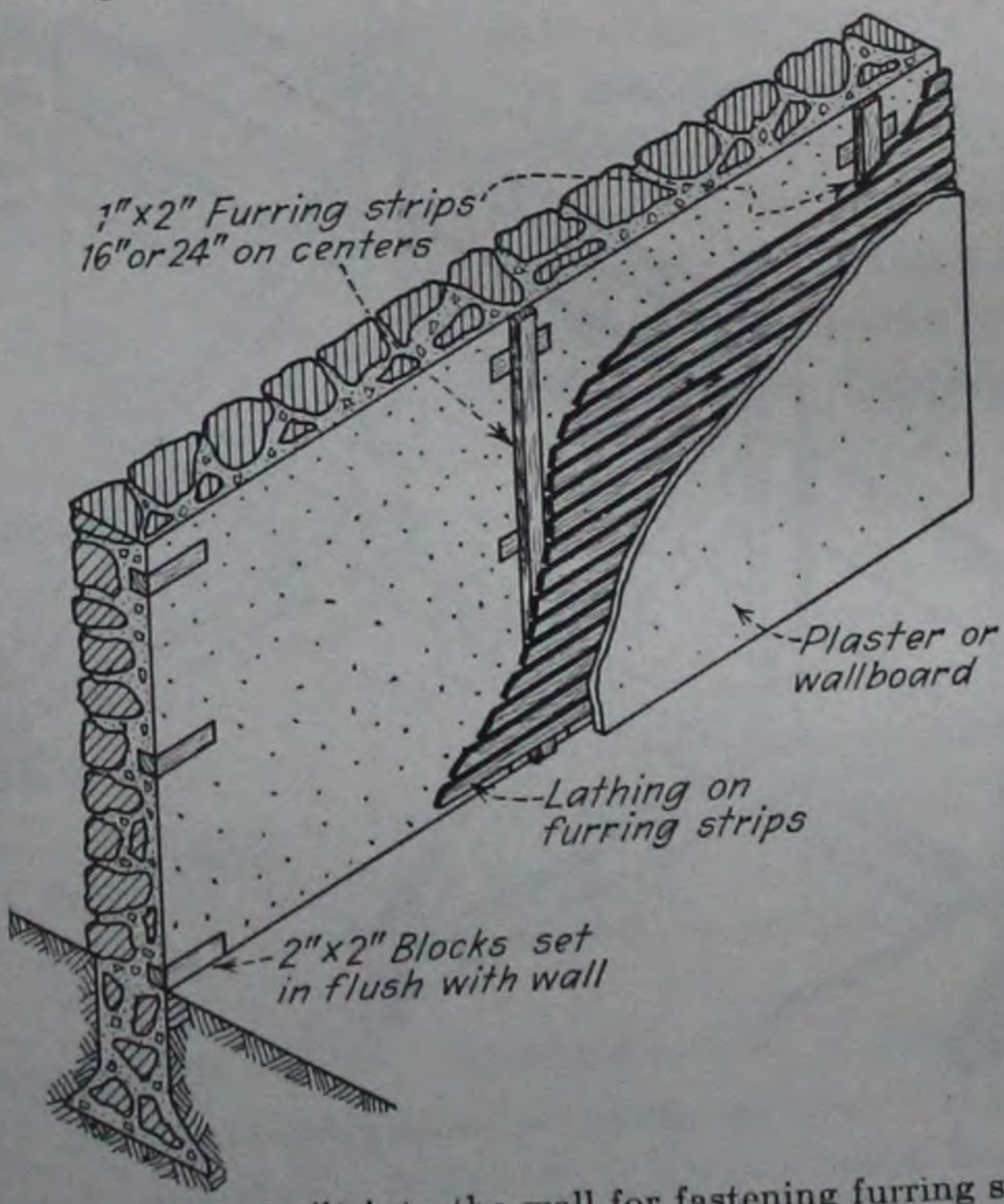

FIG. 84.—Blocks built into the wall for fastening furring strips.

to make a mushy consistency, will result in very strong, water-tight concrete. Where bank-run material, containing sufficient sand for a smooth finish, is used, a mixture of 1 part of cement to 4½ parts of bank-run material is about right. These mixes will usually not require more than 6 gal. of water per sack of cement. Use the consistency that works best on the job.

129. Outside Finish.—In general, there are two ways to finish the outer surface of the walls. The two methods are commonly known as *pointed* and *unpointed* work. In the latter the surplus mortar is raked out of the joints with a trowel after it has hardened enough so that it does not smear. By this method practi-

cally no mortar remains visible in the finished wall. In the pointed work the joints that are raked out are filled with a special mortar that seals each joint. This special mortar is made by mixing 1 part cement to 2 or 3 parts of sand. Mineral coloring materials, finely ground and thoroughly mixed in the mortar, may be used to produce colored joints, if desired.

130. Curing.—The proper curing of all types of concrete work is very important if maximum strength is to be obtained. If cobblestone walls are exposed to the sun and wind before harden-

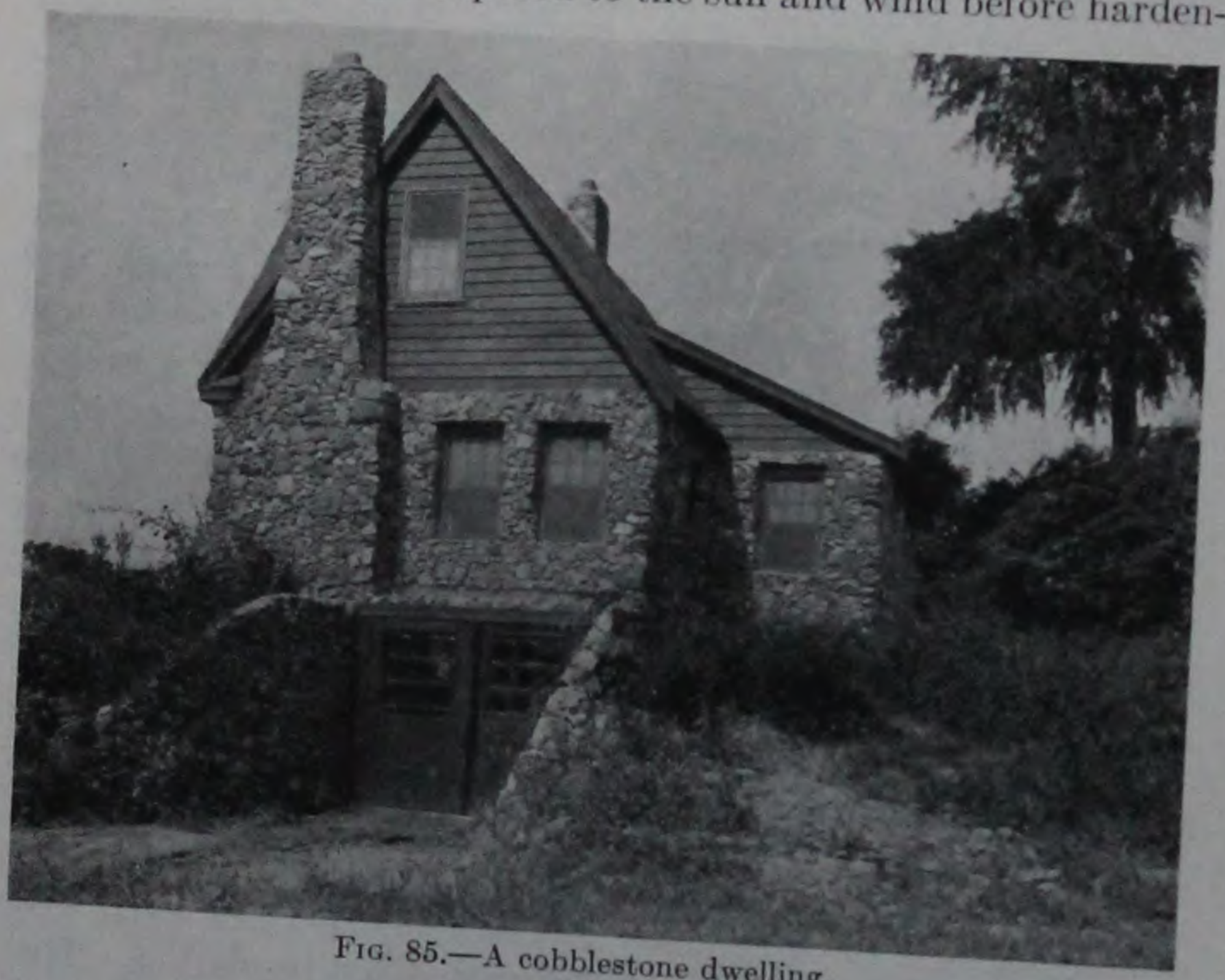

FIG. 85.—A cobblestone dwelling.

ing, much of the water necessary for curing will evaporate, and the walls will dry out. To guard against too rapid evaporation the wall should be sprinkled as soon as it has hardened enough to stand such treatment. The work should be kept moist during the early hardening period of about 6 to 10 days. On most construction jobs too little water is used after the work has been completed.

131. Estimating Materials for Cobblestone Construction.—When rock is being hauled an estimate of the number of cubic feet may be secured and the number of loads needed computed. For an 8-in. wall, $\frac{2}{3}$ cu. ft. of stone will be required per square

foot of wall, and for a 12-in. wall, 1 cu. ft. wagon-box run will be required. The amount of concrete mortar needed will vary considerably with the stone, but in most cases the volume required will be about one-third as much as the stone. An attractive cobblestone dwelling is shown in Fig. 85.

CLAY PRODUCTS

The value of clay building products is dependent on three things: the kind of clay used, the efficiency and skill of the manufacturer, and the design of the product. Clay is a very stable product that has been formed from the disintegration of feldspathic rocks. The chemical symbol for the clay from which brick is usually made in $Al_2O_2 \cdot 2SiO_2 \cdot 2H_2O$, but it is always mixed with impurities such as oxides of iron, calcium, magnesium, potassium, sodium, titanium, and sulphur. During geologic ages this clay has been moved by upheavals of the earth's crust and by the wind and water, and much has been deposited in stream, lake, and ocean beds. In some places it has been subjected to intense heat and pressure. Clays, as they are found, fall into three general classes: surface clays, either of recent formation or the upthrust of older deposits; shales, which immense pressure has reduced almost to the form of slate; and fire clays, mined, usually, at deeper levels and so called because of their refractory qualities.

132. Brick.—Brick offers many advantages as a material for farm buildings. Being in small standardized units, they can be built into almost any shape or type of structure. They furnish ample strength to carry loads imposed on structures, even when built into the thin section walls needed for insulation. They are comparatively cheap in localities where they do not need to be shipped long distances, but where there are long freight hauls the cost is considerably higher. The standardization in size and quality enables the designer to plan for their use in any locality with every assurance of good results. The size $2\frac{1}{4}$ by $3\frac{3}{4}$ by 8 in. is accepted by manufacturers as a standard-sized brick. Slight variations from this standard can be taken care of in the structure by varying mortar joints. A brick of good quality laid in cement mortar makes a permanent structure, one that requires little maintenance and that can be made as nearly fireproof as is possible in farm buildings.

The one objection frequently offered is the high labor cost for erection of brick buildings. This objection can be overcome, however, by the man who is willing to learn and eager to reduce the cost of his buildings. The farmer or his laborers can do a sufficiently accurate job, especially on small buildings, so that no expensive labor will be needed. Any farmer who can do a good piece of concrete work can lay up a brick wall for a poultry house if he will secure a few instructions from the Brick Manufacturers' Association on laying brick. The mortar joints may not all be even, but the wall could be made so that it will serve for a lifetime and still not discredit the rest of his buildings. Expert brick layers are not required in the construction of many farm buildings.

133. Kinds of Brick.—For the most part the farmer will use *common brick*. His dwelling or perhaps his barn might warrant the use of face brick, but in other buildings common brick will serve. These may be made of burned clay or of concrete. Concrete products plants in many localities make brick of good quality. Clay brick may be classed as soft (salmon) or hard-burned. The difference is partly in the burning and partly in the quality of the clay from which the bricks are made. Ordinary surface clay often makes the salmon or red-burned brick. If a small amount of shale or vitrifying clay is added, a hard-burned or vitrified brick results. Soft brick tends to be larger than hard brick, and a mixture of the two in a wall makes the work difficult. Hard brick are stronger than soft brick, but they may not make a stronger wall as they are extremely hard and impervious to water because of imperfect adhesion of the mortar. Some manufacturers overcome this drawback by using a rough-cut face to secure better bond between the brick and the mortar. Brick are sometimes made with colored and waterproofed edges for special work, but the cost is usually greater than for common brick.

134. Methods of Manufacture.—The clay, or the clay and shale mixture, is finely ground, and water is applied until a stiff mud is formed. Minerals are often added to the mixing water to secure the desired colors when the brick are burned. Anthracite coal is sometimes ground fine and mixed with clay to aid in the burning process. Clay brick are made by one of three processes: the *stiff-mud*, the *slop-mold*, or the *dry-press* method. The

stiff-mud process is probably used more than any other. The stiff mud is forced through a die of the desired shape and the units are cut to length by a wire being passed through them at the desired point. If the die is 3¾ by 8 in. and the bricks are cut off to a thickness of 2¼ in., they are said to be side-cut. If the die is 2¼ by 3¾ in. and the bricks are cut off in 8-in. lengths, they are said to be end-cut.

After shaping, the brick are placed in a drier and allowed to dry out slowly to prevent checking. When dry, they are stacked carefully in a kiln and burned.

The slop-mold brick and the stiff-mud brick are dried and burned in a similar manner; the dry-press brick can be transferred to the kiln directly for burning without going through the drying process, since the material is dry when pressed. The bricks are spaced in the kiln so as to allow free circulation of the heated gases. When heat is first applied there is a period of so-called "water smoking" during which time all the water is driven out of the bricks. This is followed by dehydration, which is the expulsion of a part of the water in composition. As the temperature continues to rise, various impurities in the clay are oxidized, and in the final heat the material is brought to various stages of vitrification. At this point the temperature will vary from 1800 to 2200°F. When the desired temperature for the material has been reached the fires are drawn, and the mass is allowed to cool slowly.

135. Testing Brick.—In selecting brick the purchaser should expect uniformity in size and shape to facilitate their use and to improve the appearance of the finished wall. The *ring* or *counterfeit test* gives some indication of the soundness and strength of the brick. If the bricks give a resounding ring (not a dull thud) when struck with a hammer, this is an indication of good quality. The general appearance, the absence of lime pockets and pits or spalls furnish further evidence of good quality. The percentage by weight of water absorbed is sometimes considered an indication of quality. When submerged in water for 24 hr., good brick will absorb not more than 10 per cent moisture by weight. A few drops of water placed on the face of a dry brick will show whether the brick will absorb water readily or not, and this test is often used as a rough indication of quality.

Hard-burned brick should be selected to use in the wall of the structure near the surface of the ground. Absorption of mois-

ture, the action of the soil, freezing, and thawing put the brick to a severe test, and special care should be given the work at this point.

136. Mortar.—Cement mortar tempered with not to exceed 15 per cent of hydrated lime, as compared with the cement by volume, is considered by builders to be cement mortar and will make a high-grade product. A mix of 1 part of cement to 3 parts of sand plus from 10 to 15 per cent of hydrated lime is recommended. If more lime is added it is called *lime-cement mortar*. The addition of the lime decreases the rate of setting and increases the workability of the mortar. To secure a good set, mortar should be kept moist for 7 days at least. The mortar is in thin sections, and if the bricks are dry it may dry out too quickly to have satisfactory strength or wearing quality. In estimating quantities of mortar, computations based on a ½-in. mortar joint will give proper amounts in most cases.

TYPES OF WALLS FOR FARM BUILDINGS

137. The Ideal or All-Rolok Wall.—In most farm buildings it is desired to have walls with good insulating value and at the same

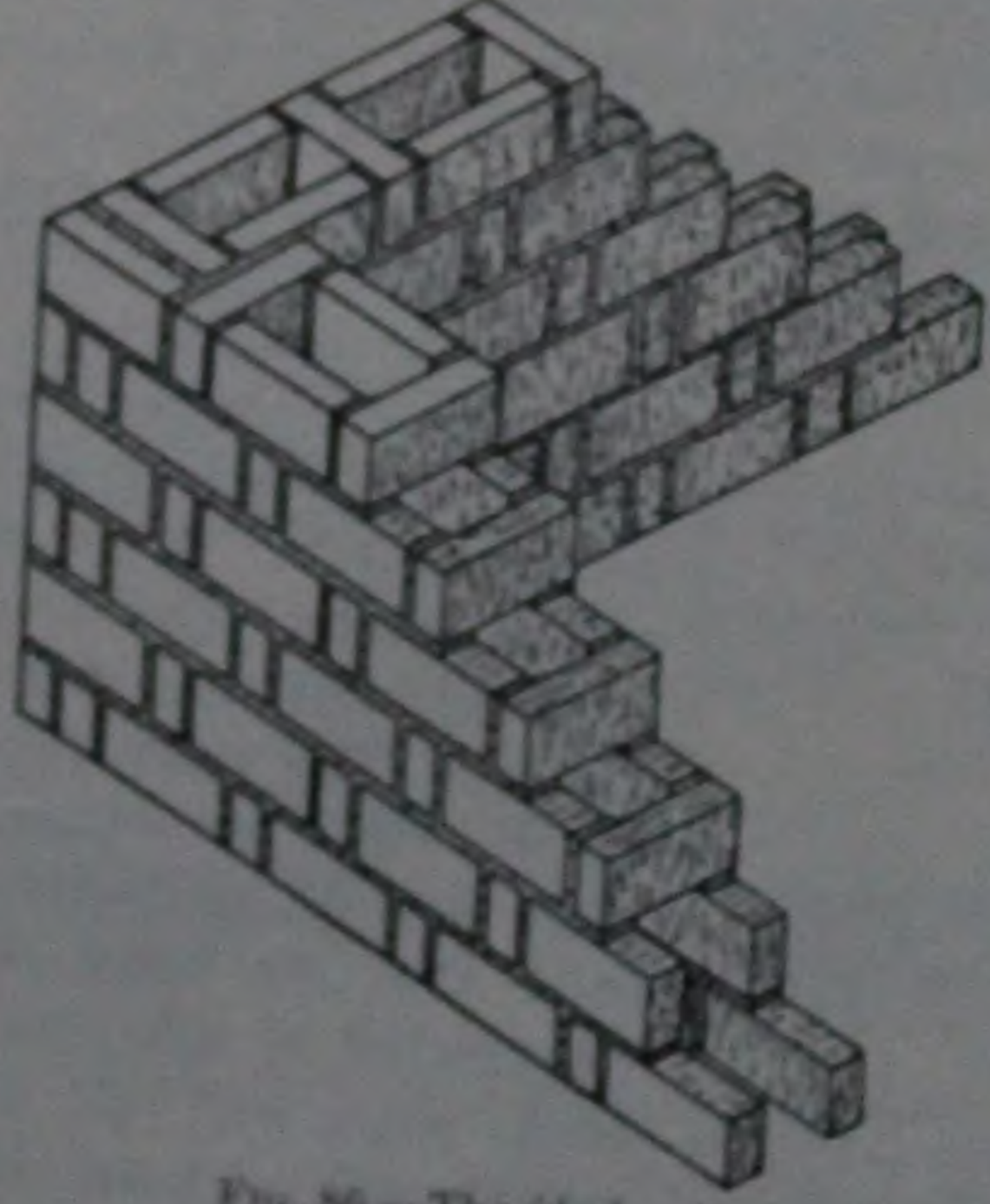

FIG. 86.—The ideal wall.

time to keep the cost as low as possible without sacrificing too much strength. The *ideal wall* (Fig. 86) is recommended for

poultry and hog houses, machinery sheds, barns, and even dwellings. In this wall all the bricks are placed on edge, making a 3½-in. air space in the center. The air spaces are all connected and permit some circulation within the wall. This type of wall requires approximately 9 brick to the square foot of wall, as compared to 12⅓ when the brick are laid in an 8-in. solid wall, and makes possible a substantial reduction in construction cost. Also, the insulation value is considerably higher than for the solid wall.

Tests by the U.S. Bureau of Standards show that the ideal or All-Rolok 8-in. wall, constructed of soft-mud, sand-struck brick, when well laid with good 1-3 mortar, will carry an average of 957 lb. per square inch (gross cross-sectional area of wall). Used in smaller farm buildings, this type of wall gives a great factor of safety.

The foundation should be laid up solid from the footing, as shown in Fig. 87. At the floor level the ideal wall can be started. The width, as well as the depth of footing, will depend on the load and the bearing power of the soil.

Basement walls may be covered outside with a coating of tar, or they may be plastered with mortar to help keep out moisture. A drain at the outer edge of the footing is desirable.

138. Rolok-bak Wall.—When a regular brick finish is desired on the outside wall and when increased insulation is desired, the Rolok-bak wall is very satisfactory (Fig. 88). In this wall six courses are laid flat on the outside and four courses on edge inside. A tie course is then put in place. The process is then repeated until the desired height is reached. This wall requires an average of 10½ brick per square foot of wall. Tests by the U.S. Bureau of Standards show that the Rolok-bak 8-in. wall constructed of soft-mud, sand-struck brick, when well laid with good 1-3 mortar, will carry an average of 1206 lb. per square inch (gross cross-sectional area of wall).

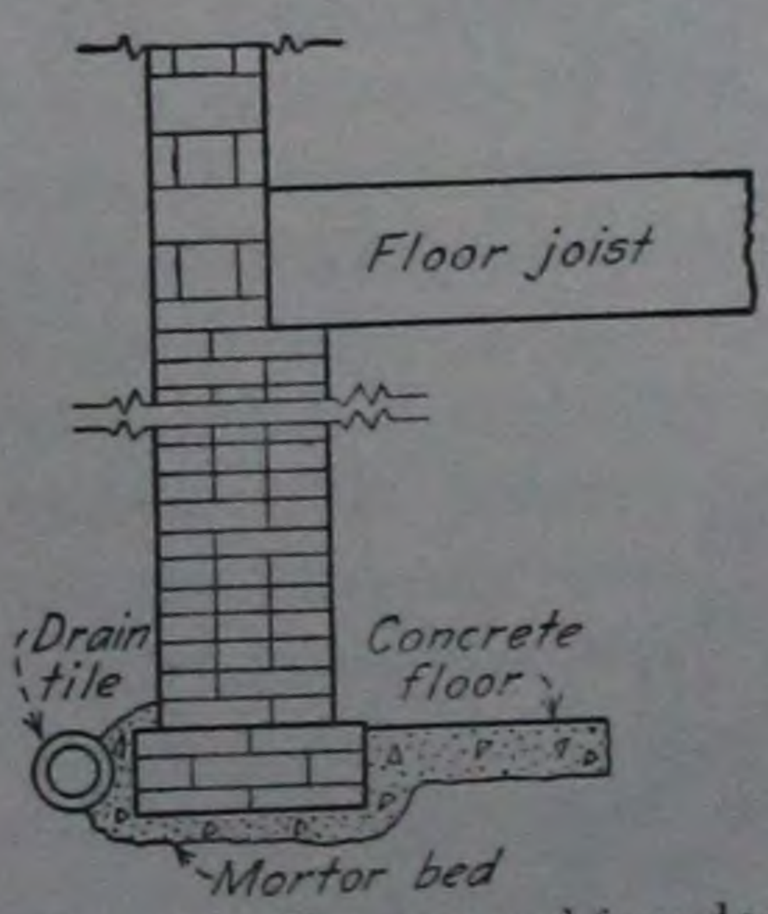

FIG. 87.—Footing and foundation for *ideal wall*.

139. Building Blocks.—Building blocks offer certain advantages over brick for some buildings. They come in larger units

and, of course, lay up faster in the wall. They may have slightly higher insulating value, depending on their design, their quality, and the care used in laying them.

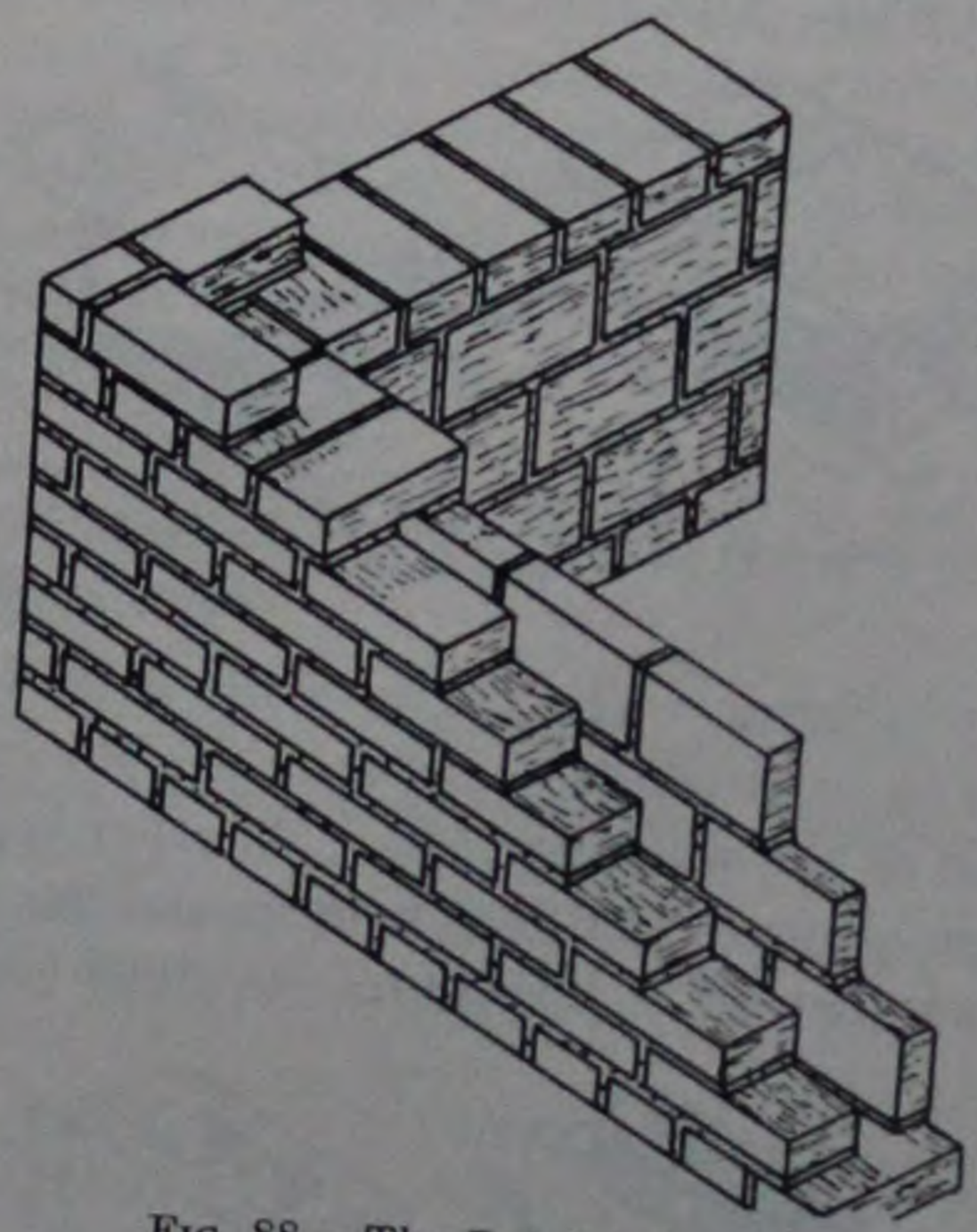

FIG. 88.—The Rolok-bak wall.

Manufacturers have standardized on two sizes of blocks for farm buildings. These two blocks, shown in Fig. 89, are designed for use in an 8-in. wall, although the small block can be laid on edge for a 5-in. wall where loads are not too great. These blocks are sold in two qualities, the red-burned and the vitrified.

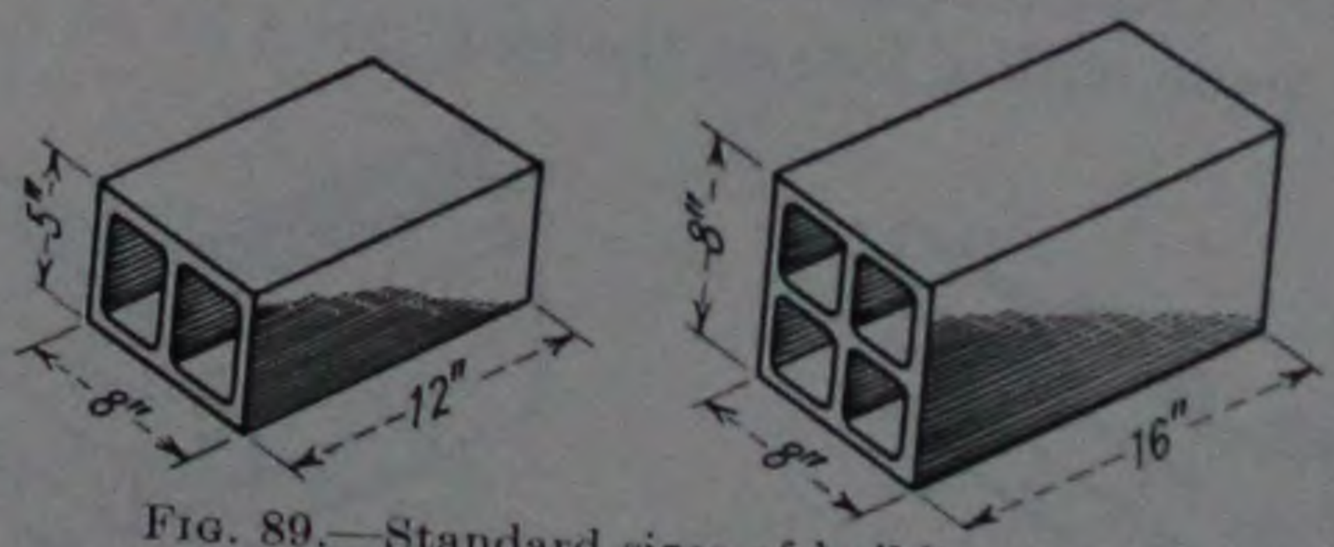

FIG. 89.—Standard sizes of building blocks.

140. Special Blocks.—In breaking joints and in fitting the wall against window and door frames, it is necessary to use half blocks. These are 5 by 8 by 6 in. for the smaller blocks and 8 by 8 by 8 in. for the larger size. Most companies manufacture

what is called a *jamb block* to fit against windows and doors. By using these blocks window frames can be recessed and a better fit secured. At the corners some special type of block is required to make a closed wall. One type of common block is cut partway

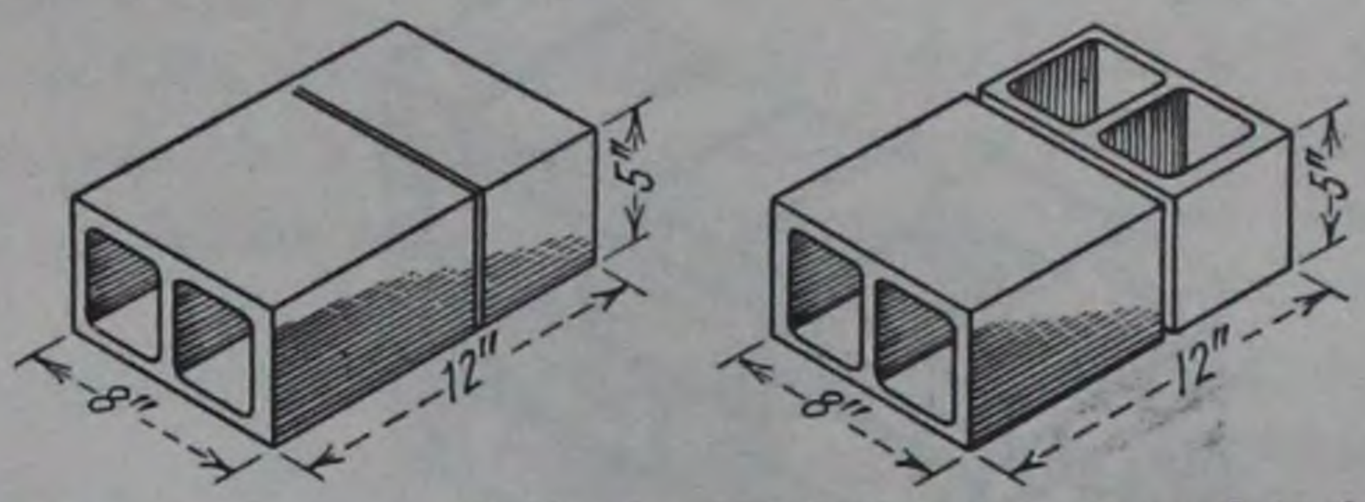

FIG. 90.—Cut block that may be broken and the piece turned to form a closed end.

through before burning. The cut is made 5 in. from one end. This block can be used whole or broken with the cut end turned to close the end of the wall (Fig. 90). Another type of common block is made in either 8- or 16-in. lengths and has vertical openings in the block instead of horizontal openings (Fig. 91).

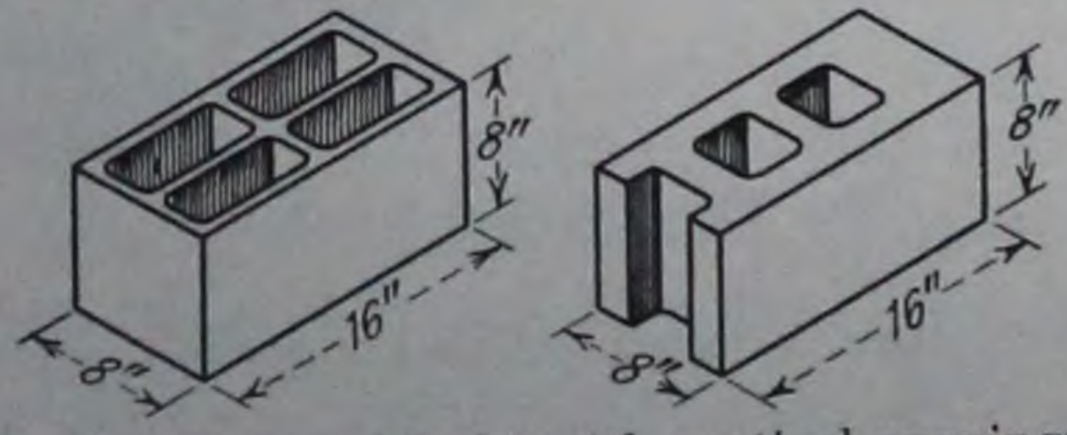

FIG. 91.—Corner blocks with vertical openings.

A concrete block known as the L-block was developed by Profs. J. B. Davidson and H. Giese at Iowa State College. It can be used in either a single or double wall as shown in Fig. 92. These blocks are made with a face on the long side 8 by 16 in. and the

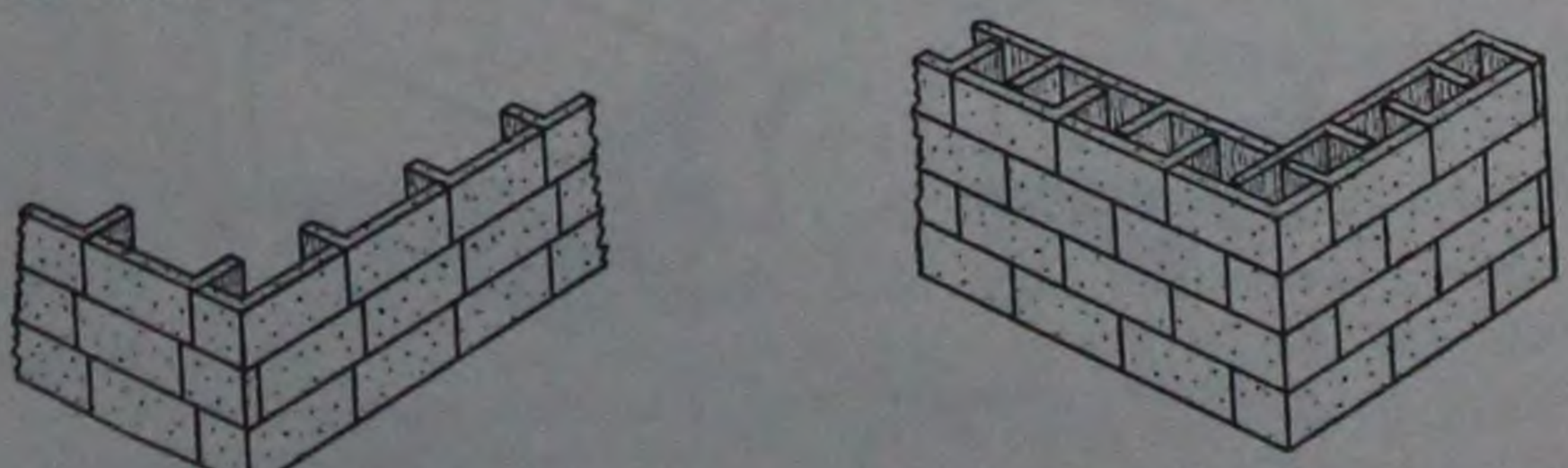

FIG. 92.—The L-block in single and double walls.

face on the offset 8 by 8 in. The thickness is about 1½ in. Between six and seven blocks can be made from 1 cu. ft. of 1-3 concrete.

Questions and Problems

107. It seems that brick would be a desirable material for farm buildings; yet only a comparatively small amount of brick construction is used. Common brick sell for about $22 per thousand and cost about $15 for mortar and labor to put them in place. Why does this situation prevail?

108. What is the comparative cost and desirability of an 8-in. solid brick wall, an 8-in. ideal wall, and an 8-in. tile wall for a machinery shed? The tile cost $60 per thousand and about $25 per thousand for material and labor to lay them. Give your answer with figures and reasons.

109. Is your city favorably located for a brick manufacturing plant? Explain.

110. If concrete blocks 8 by 8 by 16 in. cost 16 cts. each and it costs 6 cts. each for mortar and labor to lay them, what would it cost to build a wall 8 ft. high and 32 ft. long?

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CHAPTER XXIV

SIDING, ROOFING, AND INSULATION

SIDING

141. Wood.—In an earlier chapter on utilization of different varieties of wood, white pine, cypress, redwood, and walnut were recommended for outside work. These varieties take paint to good advantage, but even if they are not given a protective covering they will outlast other varieties under similar conditions. There are two general types of manufactured wood siding,

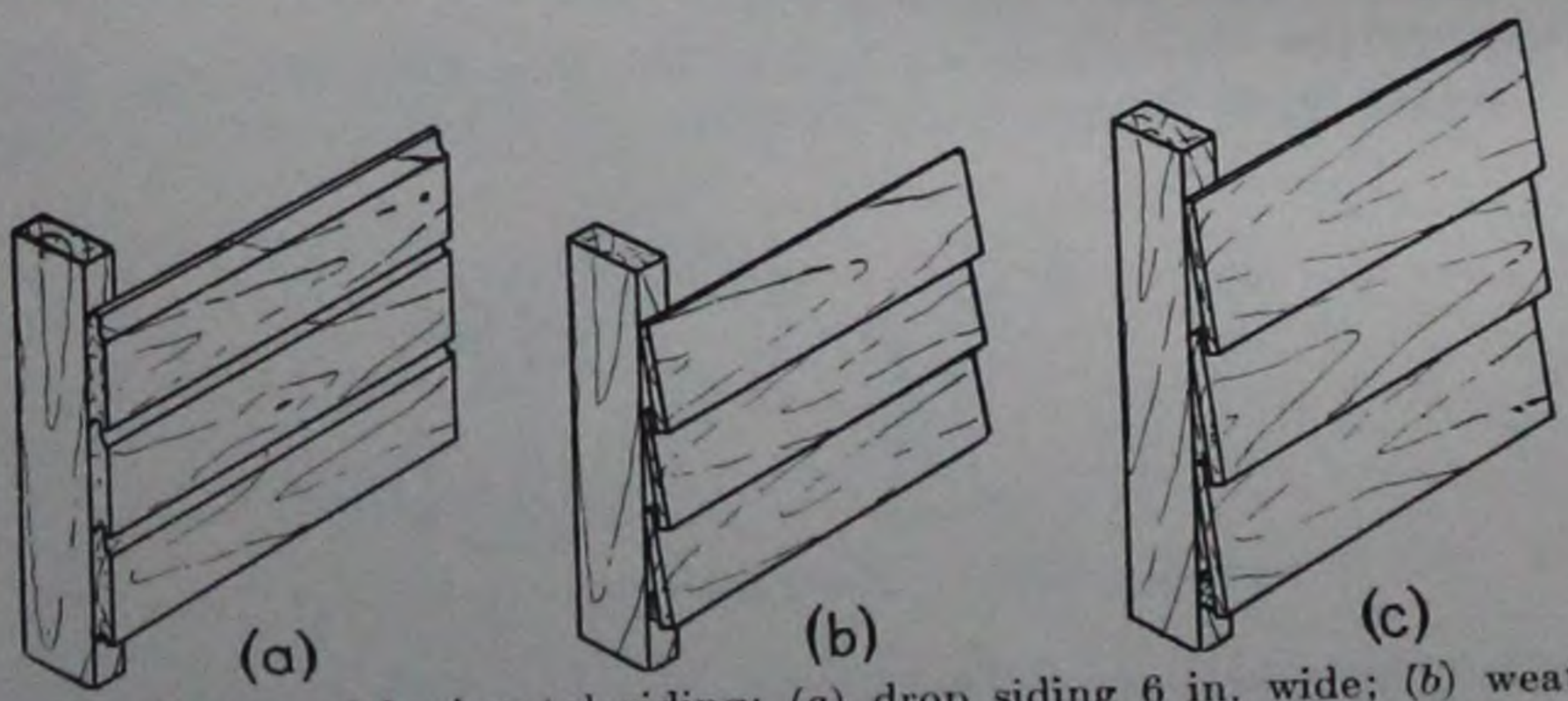

FIG. 93.—Types of horizontal siding: (*a*) drop siding 6 in. wide; (*b*) weather boards 6 in. wide; (*c*) 10-inch clapboards, 8 in. to the weather.

one type to be placed horizontally and the other to be placed vertically.

Horizontal siding (see Fig. 93) offers much greater opportunity for moisture to enter the joints between boards and to enter the grain of the wood than do boards placed in a vertical position. The drop siding shown in Fig. 93 is being used less on larger buildings because the alternate wetting and drying cause cracks to form between the boards, making an unsatisfactory covering. It can be used on low buildings where the roof gives protection from blowing rains. Weather boarding or clapboards offer less objection from this source and are used extensively as wall covering in residences. The use of clapboards for barn siding is recommended where horizontal siding must be used.

Vertical siding may be edge-matched or plain, with a batten used to cover cracks. A batten is a narrow strip of wood or metal that is used to cover the crack between siding boards. Figure 94 shows different types of battens that may be used.

The metal batten and the batten of plain wood placed inside the siding have the advantage of being better protected from

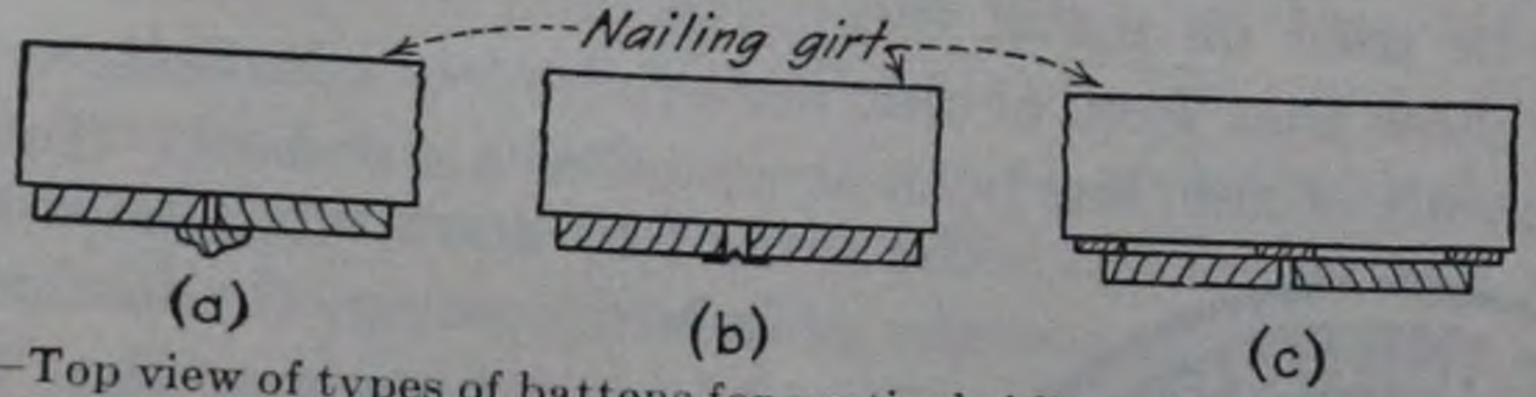

FIG. 94.—Top view of types of battens for vertical siding: (*a*) milled wood batten; (*b*) galvanized iron batten; (*c*) plain wood placed inside siding.

damage than the milled-wood batten and, as a result, will give longer service. Battens ½ by 3 in. should be used with 12-in. boards to give sufficient bearing surface for nailing. Where horizontal joints are necessary in siding care should be used to make all joints waterproof. They may be sawed at an angle and fitted carefully, or a square butt joint with a piece of tin inserted may be used. The lap joint is always safe to use but sometimes does not fit into the design to the best advantage. Figure 95 shows these different types of horizontal joints.

Good nailing is essential. A study of over a thousand barns impressed the author with the importance of this aspect of construction. Good nailing consists of using a nail large enough so that it will not be necessary to sink the head into the wood to get sufficient holding power. A common nail should be driven in only until the head is slightly pressed into the wood. Continued pounding bruises the wood and causes rapid decay.

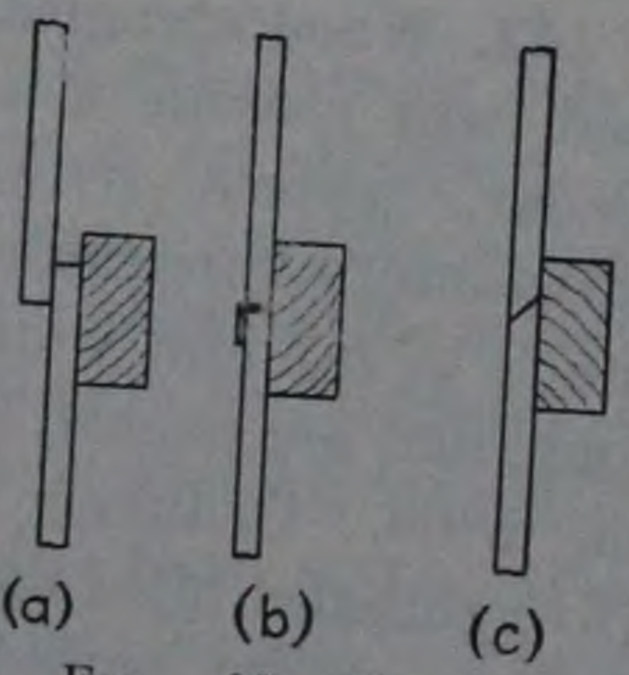

FIG. 95.—Types of horizontal joints: (*a*) lap joint; (*b*) joint with tin insert; (*c*) bevel joint.

142. Metal Sheets.—Galvanized-iron sheets are being used for siding in an increasing number of buildings. The ¾-in. corrugation makes for better appearance than the larger corrugations and will ordinarily have sufficient stiffness to stay in place. A raised-seam type known as *two*, *three*, or *five V-crimp* gives the appearance of vertical siding with battens and is very satisfactory, especially for covering old siding. The metal reduces infiltration,

and the old siding furnishes insulating value, making a good combination.

The service the galvanized-iron sheets give depends on the protection given by the zinc coating. The Zinc Institute, a research organization supported by zinc manufacturers, has carried on extensive tests to determine the optimum amount of zinc to be used on metal sheets for satisfactory service. Their studies show that 2 oz. of zinc per square foot is satisfactory, and this amount of zinc has been accepted as a standard. To enable the farmer to know when he is getting the standard coating, the institute has adopted a seal known as the "Seal of Quality," shown in Fig. 96. Manufacturers of galvanized sheets agree to use the Seal of Quality stamp on their product. The Zinc Institute keeps a constant check on the quality of products in the hands of various dealers and takes away the right to use the seal from any company not meeting the standard.

FIG. 96.—Seal of quality.

ROOF COVERING

143. Wood shingles, if made from durable species and properly laid, will provide a satisfactory, attractive, and low-cost roof. Cedar, cypress, redwood, white pine, and southern pine are satisfactory varieties of wood for shingles. Ordinary shingles are made in random widths varying from 2½ to 14 in., are 16 in. long, and are packed in bundles each equivalent to 250 shingles 4 in. wide. Ordinary shingles are known as "5-to-2 weight" (five shingles piled one on top of the other equals 2 in.). Four-to-two weight would, of course, mean heavier shingles. For wood shingles an exposure of 4 in. is recommended on one-quarter pitch, varying to 5 in. on full-pitch roofs. Wood shingles are not recommended on pitches less than one-quarter. The proper spacing of shingles as they are laid is very important. Dry shingles should be laid ¼ in. apart and green or wet ones, about ⅛ in. apart to allow for the swelling that occurs during damp weather. Each shingle should be fastened with two nails about ⅝ in. from the edges and about 6 in. from the butt. Joints should be broken at least 1½ in., and all nails should be covered. Shingle stains improve the appearance of the roof and if they contain creosote have value as a preservative.

Wood shingles are often placed on so-called "open sheathing." Narrow boards (1 by 4 or 1 by 6 in.) are spaced about 1½ in. apart on the rafters, and the shingles are placed the same as for solid sheathing.

144. Asbestos shingles are made by compressing asbestos fiber and Portland cement under great pressure. They are strong, durable, and fireproof. The natural color of this shingle is similar to that of Portland cement and produces a roof surface that is rather cold in appearance. To meet architectural requirements they are now made in a wide variety of colors and surface textures. The color is produced by veneering the exposed surface, by incorporating mineral pigments throughout the body of

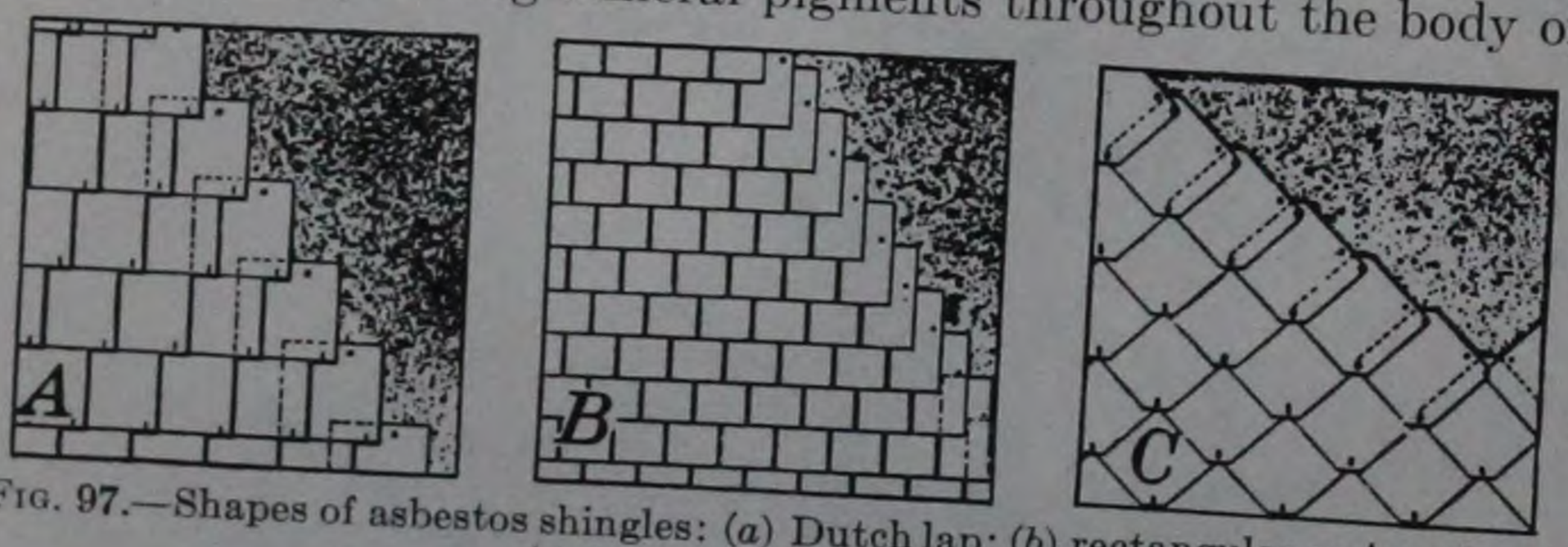

FIG. 97.—Shapes of asbestos shingles: (*a*) Dutch lap; (*b*) rectangular or American; (*c*) hexagonal or French.

the shingle, or by pressing fragments of colored slate or other materials into the exposed surface. There is no standard by which to judge between the merits of the many variations, and the small buyer should be guided by the reputation of the manufacturer or by the service given by these shingles on buildings in his locality. The roof framing should be checked for strength, since these shingles have much more weight than some other kinds of roofing, running from 275 to 500 lb. per square.[1] There are three types or styles of asbestos shingle, based on shape and method of application: the side lap or Dutch lap (Fig. 97*a*); the rectangular or American (Fig. 97*b*); and the hexagonal or French (Fig. 97*c*). The type of architecture being followed in the building group should govern the selection.

145. Bituminous roofing is marketed in several classes: the simple impregnated felt known as *tar paper*, heavily coated felt in rolls known as *roll roofing*, and composition shingles, or shingle strips. The basis of these products is a felt composed of rag, paper, jute, or similar material. In manufacturing, the felt is

[1] One square = 100 sq. ft.

passed through a vat of hot tar or asphalt until it is thoroughly saturated. These roofing products may be made up in single, double, or triple ply and may be covered on the weather side with mineral granules. Roll roofing is suited to pitches of one-quarter and less. Where it is used on flat roofs it is usually placed horizontally, but on steeper roofs placing the strips vertically seems to be more satisfactory. This type of roofing is not well

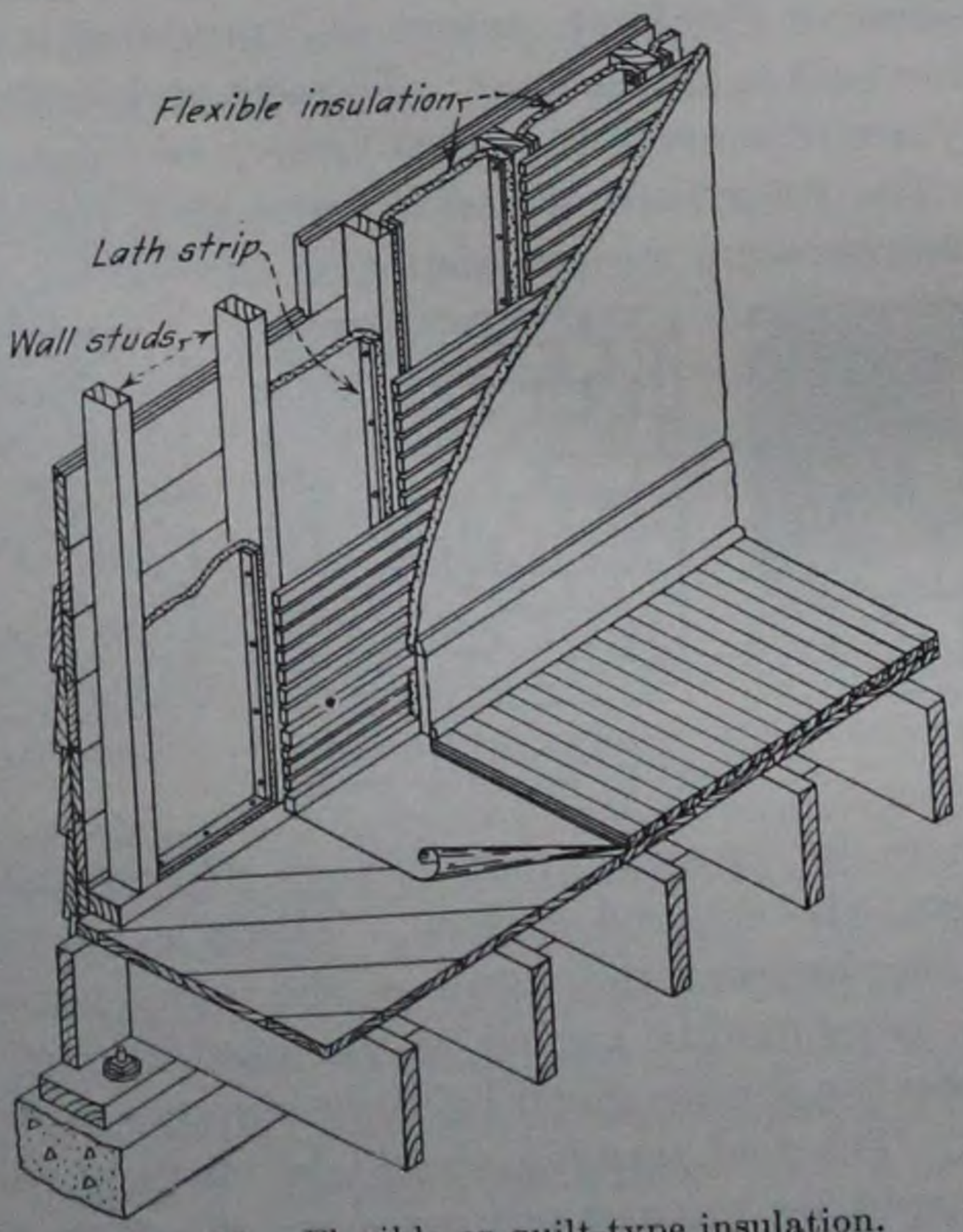

FIG. 98.—Flexible or quilt-type insulation.

adapted to open sheds unless heavy paper is closely nailed to the sheathing to prevent the wind pressure from lifting the roofing and causing it to break. Roll roofing comes in 36-in. width, with 108 sq. ft. in a roll. This will cover one square (100 sq. ft.) when applied. Its weight varies from 30 to 87 lb. per roll, depending on the number of ply and the presence or absence of mineral covering. Shingles come in $12\frac{3}{8}$ by 9 in. or in four-in-one strips $12\frac{3}{8}$ by 36 in., and from 100 to 136 are required per square. The weight per square is about 240 lb.

Building paper is made in two kinds, ordinary tar paper and rosin-sized paper. Rosin paper is used on the sheathing under

tin roofs because the unneutralized acids of tar paper tend to corrode metal. Tar paper is used to cover sheathing under siding and is also used under asphalt shingles.

146. Galvanized roofing may be secured in corrugated, standing seam, or the V-crimp type. It can be placed on strip sheathing and, when properly fastened, forms a good roof. Instead of the ordinary 1-in. sheathing, 2-in. material spaced at varying distances up to 3 ft. makes a satisfactory sheathing. This spacing is possible because of the increased strength of the roofing materials and the additional holding power of the nails in the 2-in. stock. Specially galvanized nails fitted with lead washers are driven into the top of the corrugation or crimp to prevent leakage around the nails. Special zinc paint can also be used for extra protection to nails or to protect sheets that have too light a coating of zinc. Corrugated sheets are lapped one corrugation to make a waterproof joint. Galvanized sheets may be damaged by improper storage in the yards and should be inspected before being used on the job. Galvanized roofing gives little protection from heat or cold, but if insulation is needed it can be supplied under the roofing and satisfactory results obtained.

147. Reroofing.—In some instances asphalt shingles or metal roofing has been used to cover wood shingles. Where metal roofing is used it is usually applied over 1- by 2-in. horizontal strips to provide an air space under the metal. Condensation that collects will thus have a better chance to evaporate without causing damage. In a great many cases asphalt shingles are applied to old wood-shingle roofs, the only preparation made being a thorough nailing on of the old shingles.

INSULATION

148. Insulation Materials.—There are two general classes of materials from which insulating products can be made. They are vegetable or plant fiber and materials from mineral sources. Wheat and flax straw, cornstalks, cane fiber, and seaweed are the principal sources of vegetable fiber in use. Wood pulp, formerly a waste product from lumber mills, is now being made into insulating material. Molten limestone, heated to fusion in the process of refining iron ore, was formerly cooled and transported away from the plant as a waste product, but now it is taken in

the molten condition and made into insulating material without the expense of reheating.

Four general types of insulation materials are on the market: the *filler* or granular, *quilt* or blanket, *board* or structural, and the *foil* type. The filler type can be blown or tamped into walls already built or spread over the lath between joists in an attic. The quilt type (see Fig. 98) is made in rolls or bats the proper width to fill the space between studding and the rafters. The

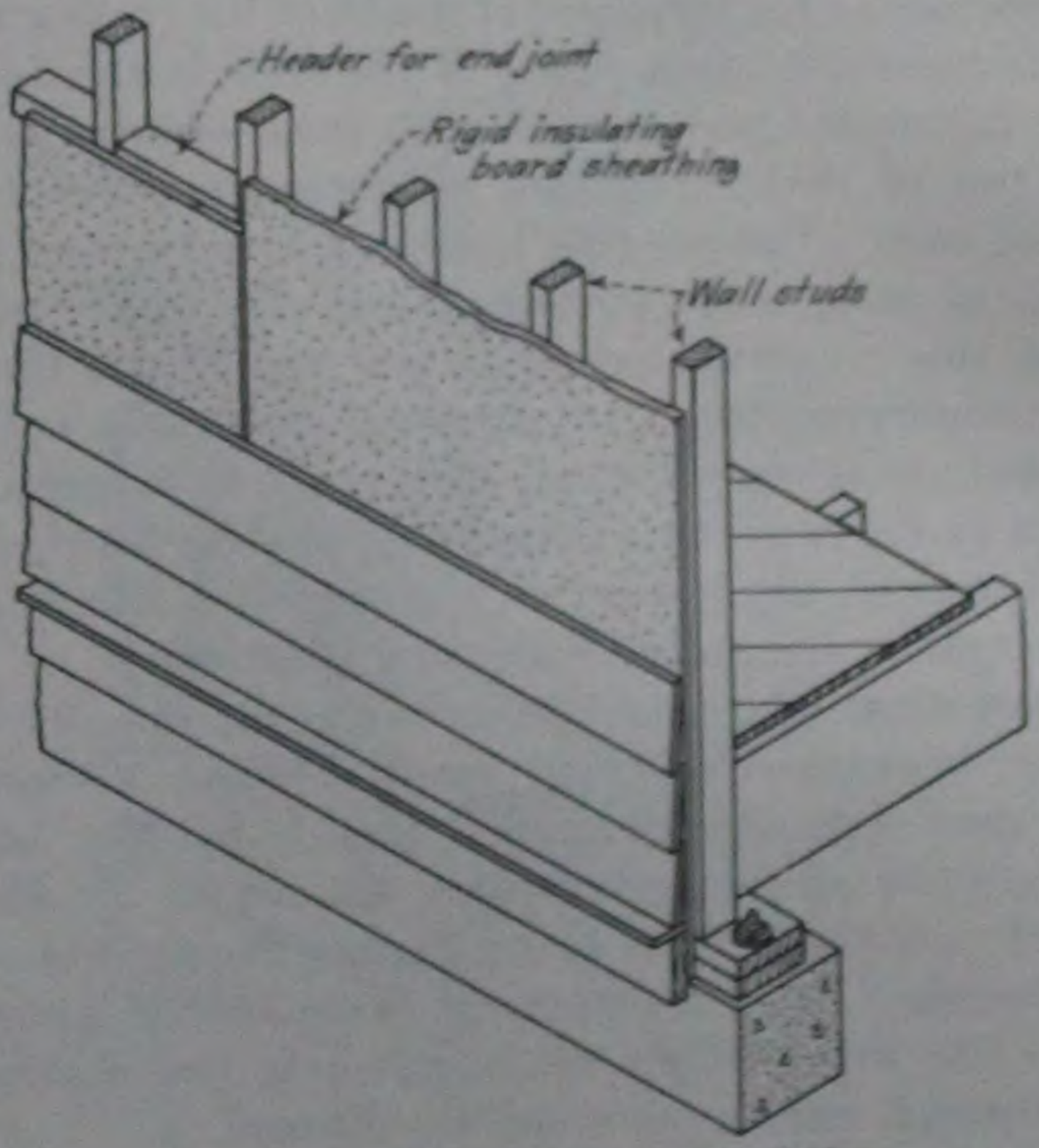

FIG. 99.—Rigid or structural insulation.

structural type (Fig. 99) is made in slabs or boards in varying thicknesses, ½ in. being the most common thickness, and in 4-ft. widths. The standard lengths in common use of the structural type are 8 and 12 ft. The foil type is marketed in rolls and is applied in much the same manner in which wallpaper is applied.

Questions and Problems

111. Why do designers specify horizontal siding in many building plans? Is it better than vertical siding? Justify your conclusion.

112. Of what importance is the "Seal of Quality" on sheet-metal products?

113. A farmer writes, "I would like to have a uniform roof covering on all my farm buildings. I have roof pitches varying from one-eighth to full pitch." What kind of covering would be best to use?

114. My dealer tells me that he has four kinds of insulating products, foil, fill, quilt type, and structural. I want to insulate the attic of my house. Which would be preferable? Should it be used on joists or on rafters?

115. A man owns a mushroom cellar. The sides are banked with earth. The cover is made so that it has a U value of .12. The underside of the rafters is covered with ¾-in. yellow pine. The inside relative humidity is 85 and inside temperature is 55°F. When the outside temperature goes down to 15°, moisture collects on the ceiling. Would foil insulation correct this trouble?

116. At what outside temperature would the trouble appear again?

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"Wood Handbook," Forest Products Laboratory, Madison, Wis.

PART V

Structural Design

CHAPTER XXV

CARE, REPAIR, AND REMODELING

In the design of a machine the manufacturer studies the different parts that will receive the greatest amount of wear and provides for an abundance of lubrication to decrease this wear and prolong the life of the machine. In farm buildings, no doubt, certain parts are subjected to early failure unless the proper care is given them. In the building study made by the author in northwest Missouri, an attempt was made to locate the points of failure or most rapid deterioration in farm buildings and, where possible, to determine the cause of the failure. The points of failure in the order of their frequency were as follows: sills and connected framing, foundation, siding and doors, roof covering, roof trusses, joists, and girders.

149. Causes of Failure in Farm Buildings. *Roof Drainage.*— The most apparent cause of failure in farm buildings was the failure to provide eave troughs, downspouts, and connected drains. The damage resulting was evident in rotted sills, framework, and siding. A large amount of water drains from roofs and in dripping onto the ground splashes up onto the siding, carrying some soil with it. If wind is blowing, the water from the roof is blown against the siding and in most cases finds its way through to rot sills and girts. A study of 215 barns was made to determine the value of spouting to the life of the structure. One group of 186 barns were not spouted and showed an annual depreciation rate of 2.32 per cent. The other group of 29 barns that had similar construction but were spouted had an annual depreciation rate of 1.64 per cent. This shows a 29 per cent decrease in serviceable life for the unspouted buildings.

Foundations.—Many foundations were found to be the contributing cause of rapid deterioration. Foundation walls were often built too low. Some were placed too shallow to be safe from damage by erosion, from lack of drainage, or from heaving effects of frost, and many times they had been built without reinforcement. In a study of height of foundations, including 427 larger service buildings, 176 with foundations under 8 in. had an annual depreciation rate of 3.26 per cent. In 251 cases the foundations were higher than 8 in., and the annual depreciation rate was 2.28 per cent. This indicates a 30 per cent decrease in the life of buildings having foundations less than 8 in. above ground, as compared to buildings having higher foundations. Good foundations were often ruined through lack of drainage or through erosion where water had not been properly taken care of. It was not possible to evaluate these damages, and therefore no statistical studies were made.

Lack of Paint.—Another important cause of rapid depreciation in farm buildings was lack of paint. Many buildings had been painted several times, but protection received was not satisfactory because of the quality of siding used and the failure to cover resin spots before applying the prime coat. Table 35 reports a comparison of painted with unpainted service buildings on the farms studied. This study indicates that the first coat of paint after the barn is constructed is very effective, adding 24 per cent to its serviceable life. The buildings receiving paint as needed were given a 44 per cent increase in life as a result of paint.

TABLE 35.—EFFECTIVENESS OF PAINT IN INCREASING SERVICEABLE LIFE OF BUILDINGS

Treatment	Number of cases studied	Years of service	Increase in life due to use of paint	
			Years	Per cent
Not painted	115	37.06		
Painted when built but not after	66	45.86	8.80	24
Painted as needed	92	53.19	16.13	43.5

A study was made to determine the returns on money invested in paint. The investment in paint was credited with the annual

depreciation charge and the interest charge on the building for the years of extended life due to painting. Using the formula for compound interest, the rate of interest on the investment in paint compounded annually was determined. The cost of paint was computed on the basis of 500 sq. ft. per gallon for first coat work and 700 sq. ft. per gallon for second and third coats. Paint was figured at $7 per gallon applied. Three coats were allowed for new structures and one coat each 10 years thereafter on buildings that were considered by the farmer to have been painted as needed. This was not enough paint to give the best protection but was used because this was about the practice followed on the farms studied. Buildings of similar quality and construction were used in the study as nearly as possible. The first painting was more important than any other, yielding 3.73 per cent interest. Keeping the buildings painted did not bring such a high rate of return, 3.22 per cent. However, considering other advantages that come from keeping buildings painted, it makes a good investment.

Mechanical Repair.—The lack of mechanical repair was evident in many buildings. Siding had been split and broken by animals. This admitted rain, cold, and snow and resulted in rotted sills and floors in many cases and, of course, in cold, drafty buildings. Lack of uniformity of damage from this cause made it impossible to evaluate the results for study.

Roofing.—A great variation was found in the life of roofing. In some cases the short life was due to improper use of materials; in others, to inferior workmanship in application. Many farmers hold the opinion that wood shingles or an interlocking type of asphalt shingles are best for steep roofs (one-half pitch or more.) Many opinions were expressed to the effect that one-fourth pitch was the lowest practical limit for wood shingles. Many were enthusiastic about galvanized roofing, although they had experienced some trouble with this type on open sheds where the wind could cause a lifting action. Many were of the opinion that roll roofing was satisfactory for temporary buildings only.

Poor workmanship was evidenced in careless nailing of wood shingles, improper selection and use of nails on metal roofs, and in damage to asphalt shingles by workmen walking over them in hot weather or from fastening scaffolding at the time the shingles were applied.

Faulty Design.—Poorly designed splice joints in siding were a very evident cause of failure. A common butt joint, unless waterproofed in some way, may be the cause of failure of girts or posts and may in this way be the cause of failure of the whole structure.

Faulty design of roof supports was evident in a large number of barns. The weight of the roof and the pressure of hay against wall posts and roof supports had caused many barns to spread at the center, allowing the roof to sag. This not only was unsightly but resulted in wracking the whole roof structure, which would, of course, very materially shorten the serviceable life of the building.

Improper design and construction of doors was evidenced in many cases. Doors receive an excessive amount of use as compared to other parts of a building and in many instances were in a bad state of repair. Inadequate hardware, lack of bracing, and lack of paint were most likely causes of the failures that existed.

State of Repair of Buildings.—Under normal conditions the average mechanical value of buildings would be expected to be midway between the replacement cost and their junk value at the time of failure. Some buildings would be new, and some would be at the point of failure, so that the average would be halfway between these two limits. In the study of buildings on 200 farms in northwest Missouri, the present worth was found to be slightly greater than half the replacement cost, showing the buildings to be in a little better than average state of repair.

In the matter of repair the old adage "a stitch in time saves nine" is very applicable. A tile drain to carry roof drainage away from a building, a new board installed to replace a damaged one, a diverting ditch to remove yard drainage, the renailing of hinges, etc., may require a little time but will result in keeping a building up to the highest possible standard of service and add to the appearance and satisfaction in its use in the enterprise. Such general annual repairs, including painting, have been found to cost approximately 0.57 per cent of the first cost of the building. If these repairs are made as needed this expense will be kept at a minimum, and the serviceable life of the buildings will be increased sufficiently to more than cover costs on buildings that are meeting the needs.

150. Replanning to Meet Changing Needs.—Well-constructed farm buildings serve over a long period of time. Studies of a

large number of farms show the serviceable life of barns to vary from 25 to 100 years, depending on the design, care, quality of materials, and workmanship used in their construction. The mode for the annual depreciation rates for barns on 200 Missouri farms was as follows: hay and feeding barns, pole frame, no foundation, 3.44 per cent; hay and feeding barns with timber-frame, rock or concrete foundation, 2.07 per cent; dairy barns, balloon or timber frame, concrete floor and foundation, 1.6 per cent. During such a period of time the change in demands and, consequently, in prices, the development of new crops and methods, and the changes in soil fertility may call for a different kind of building on the farm. It is not usually an economical procedure to tear down a building and rebuild it, but it is always possible to remodel and change buildings to improve their use-fulness. A noted architect once made the statement that a house should never be considered fixed and unchangeable but should always be subject to change and improvement. The fact that a house or a barn is not convenient is no reason for going ahead and putting up with it as long as it will stand. Life is too short to bother with poorly arranged, time- and labor-consuming buildings. An automobile junk yard is said to be an evidence of progress. No doubt cars are pulled to this yard that could be made to serve further, but since the newer cars offer much more in convenience, pleasure, and service, we cannot afford to use the old. We cannot move our obsolete buildings to the junk yard, but we work them over and bring up to date as the new discoveries and developments require.

Another reason for remodeling comes from the fact that farms change hands, and the interests and qualifications of the new owners may differ widely from those of the man who planned the buildings originally. A farm may have been provided with buildings suited to the production of beef cattle and hogs and sold to a man whose interest is in dairying, or vice versa. In either case, remodeling will be necessary. A decrease in the acreage of cultivated crops, with an increase in hay and pasture acreage and consequent increase in livestock that has been found necessary on a large number of farms, creates the need for a change in the building equipment that can often be met by remodeling, making additions, etc.

151. Remodeling and Repairing Farm Buildings. *Foundations.*—In cases where the foundation has been the cause of failure, it will be necessary to support the building in sections and build a new foundation to correct the defects in the old. In many instances a building has failed by rotting of the lower 2 ft. of the walls and frame. If the walls could be cut off 2 ft. above the old foundation and the new foundation built 2 ft. higher than the old, the building would be given a new lease on life and serve a long time. This procedure cannot be accomplished at one stroke but must be carried out a little at a time. A short section can be raised to a point slightly higher than its final position and

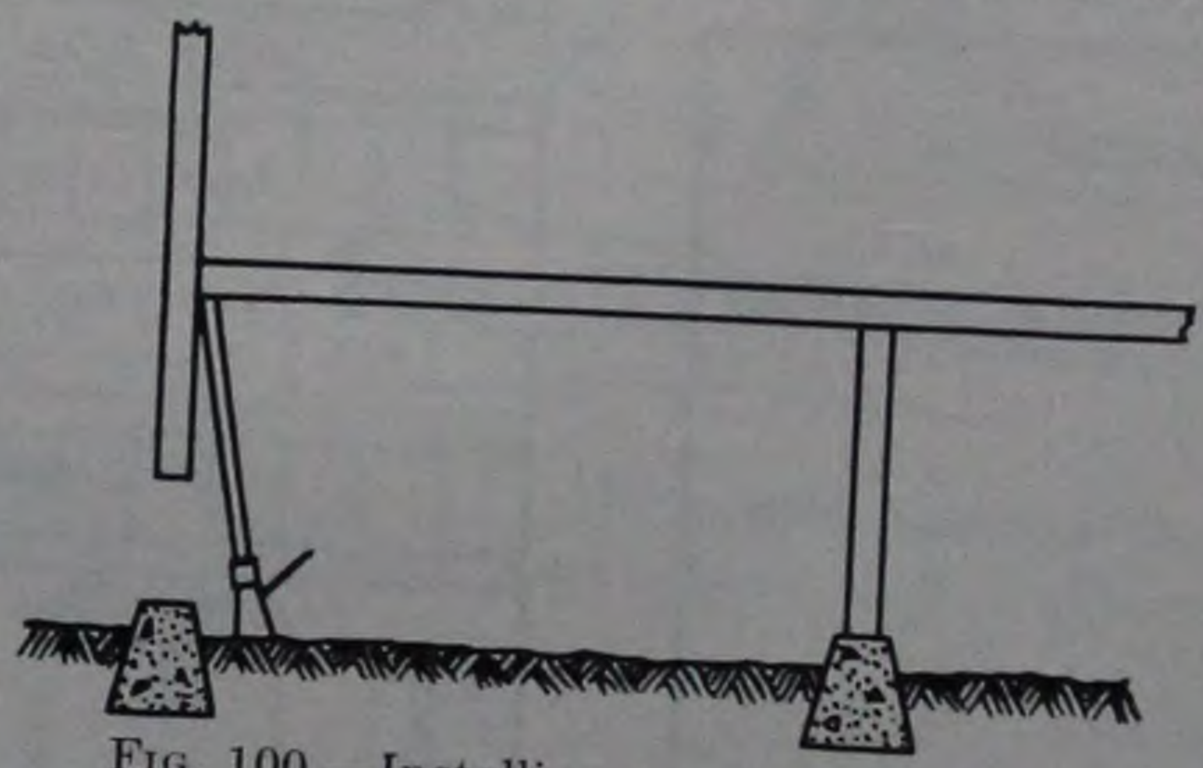


FIG. 100.—Installing a new foundation.

the studding or posts cut to the proper length to rest on the sill placed on the new foundation (see Fig. 100).

Where the old foundation can be used for a footing, concrete blocks are very convenient for building up the additional height of foundation wall. The new sill can be placed, and after the mortar has set the structure can be lowered onto this new foundation. A new section can then be raised and the work carried on to completion.

Roof.—The roof is usually in need of attention on an old building. The present roof may be covered with asphalt shingles; it may be stripped and a galvanized iron roof installed, or it may be best to remove the old covering and replace it with a new roof of the same kind if it has been satisfactory. Siding may need renailing; or it may be necessary to replace some boards; or it may be advisable to cover the siding with galvanized iron sheets. The old siding will provide insulation and, if kept dry, will serve for a long period of years.

Floor-plan Arrangement.—For floor-plan arrangement consult preceding chapters on the different enterprises. The width of the old barn, the placing of posts, etc., may require some modification, but general principles may be made to apply. Changing a floor plan usually involves labor rather than a cash outlay and may be made at a time when other work is not pressing. By studying the needs and planning carefully, many inconvenient barns can be made to serve an enterprise effectively. The first thing is to draw a floor plan of the existing layout to scale, showing posts and other parts that cannot be moved.

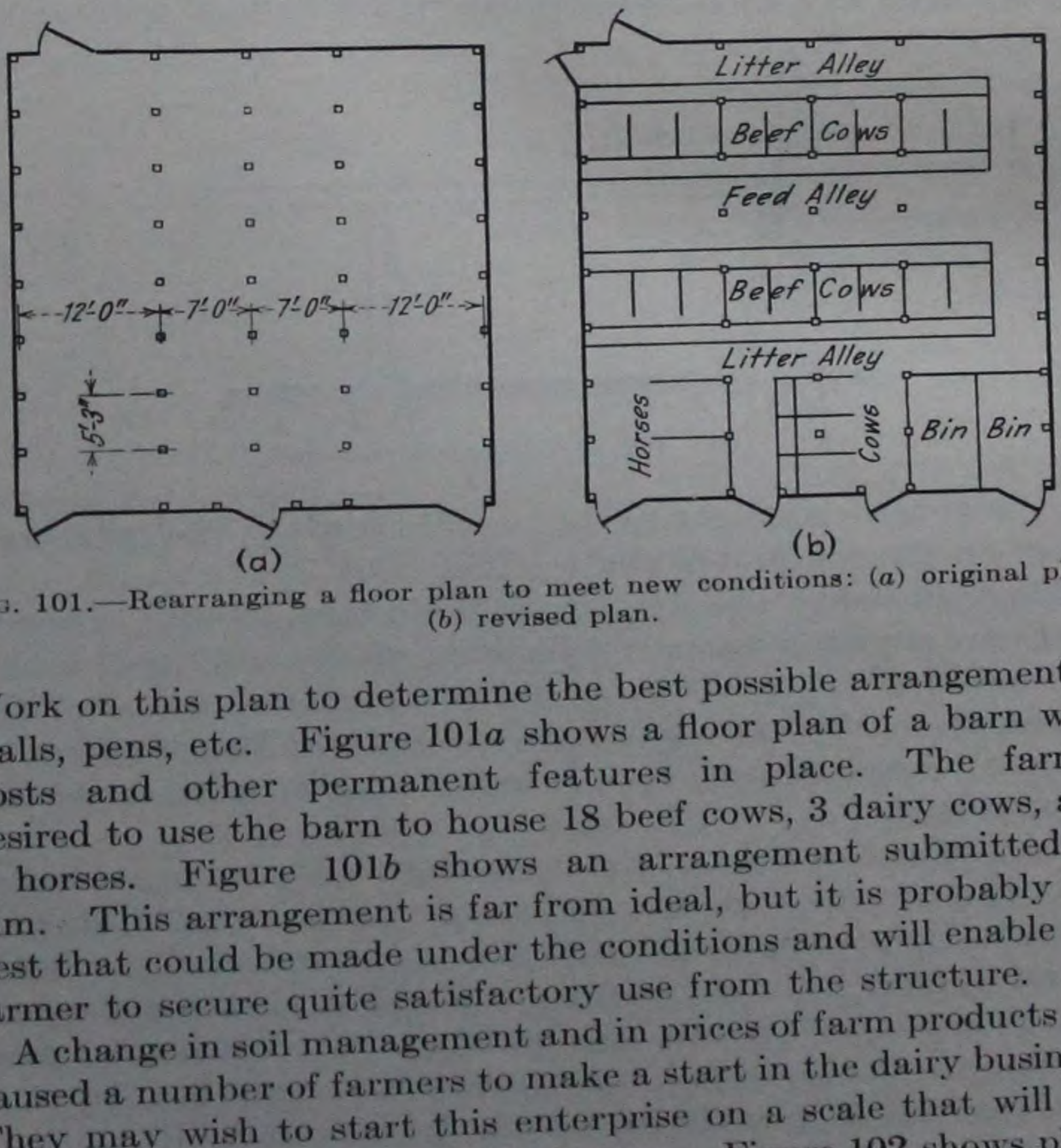


FIG. 101.—Rearranging a floor plan to meet new conditions: (*a*) original plan; (*b*) revised plan.

Work on this plan to determine the best possible arrangement of stalls, pens, etc. Figure 101*a* shows a floor plan of a barn with posts and other permanent features in place. The farmer desired to use the barn to house 18 beef cows, 3 dairy cows, and 2 horses. Figure 101*b* shows an arrangement submitted to him. This arrangement is far from ideal, but it is probably the best that could be made under the conditions and will enable the farmer to secure quite satisfactory use from the structure.

A change in soil management and in prices of farm products has caused a number of farmers to make a start in the dairy business. They may wish to start this enterprise on a scale that will not warrant investment in a new structure. Figure 102 shows plans for adding to existing barns to accommodate a small number of cows.

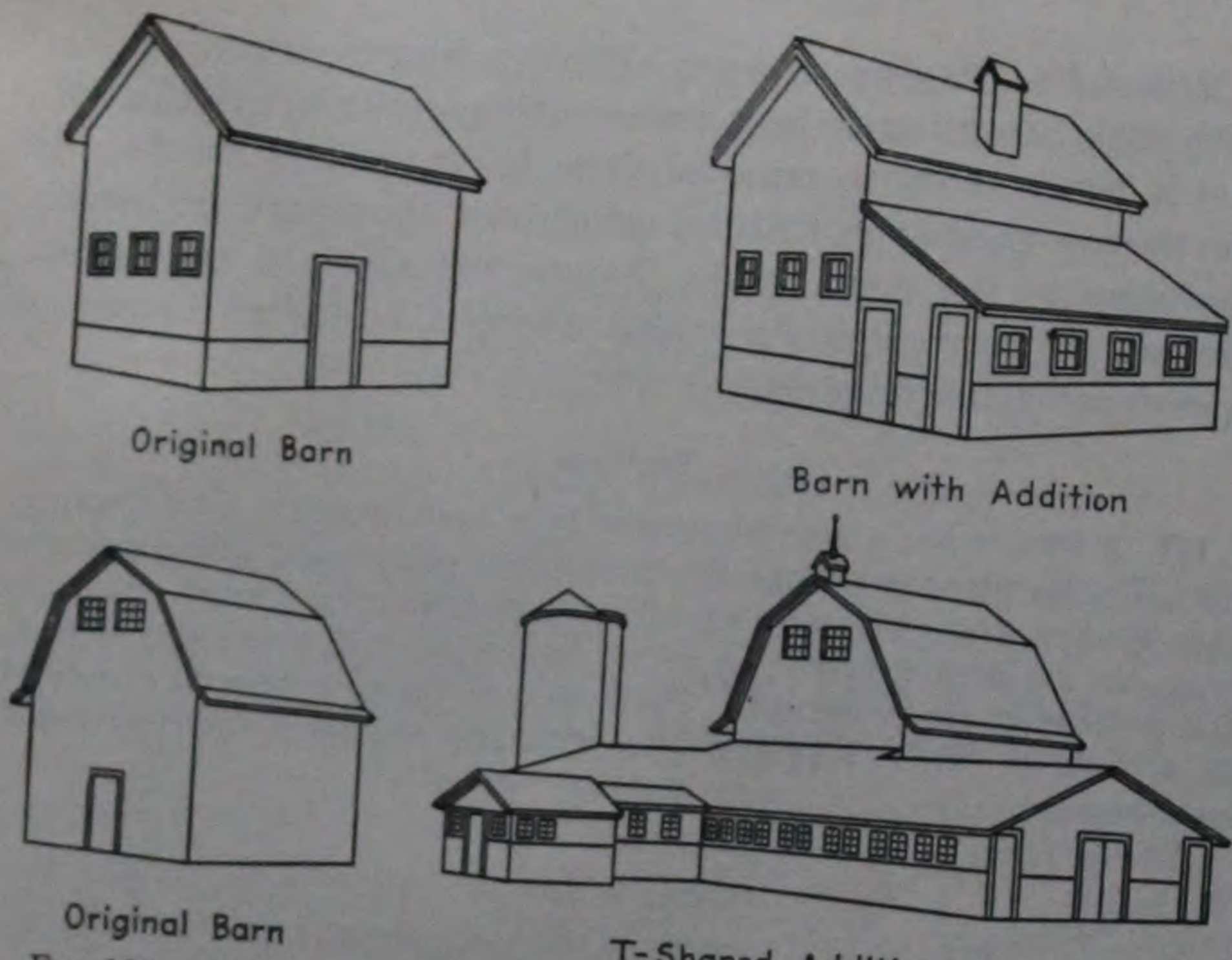


FIG. 102.—Additions to existing barns to accommodate a dairy enterprise.

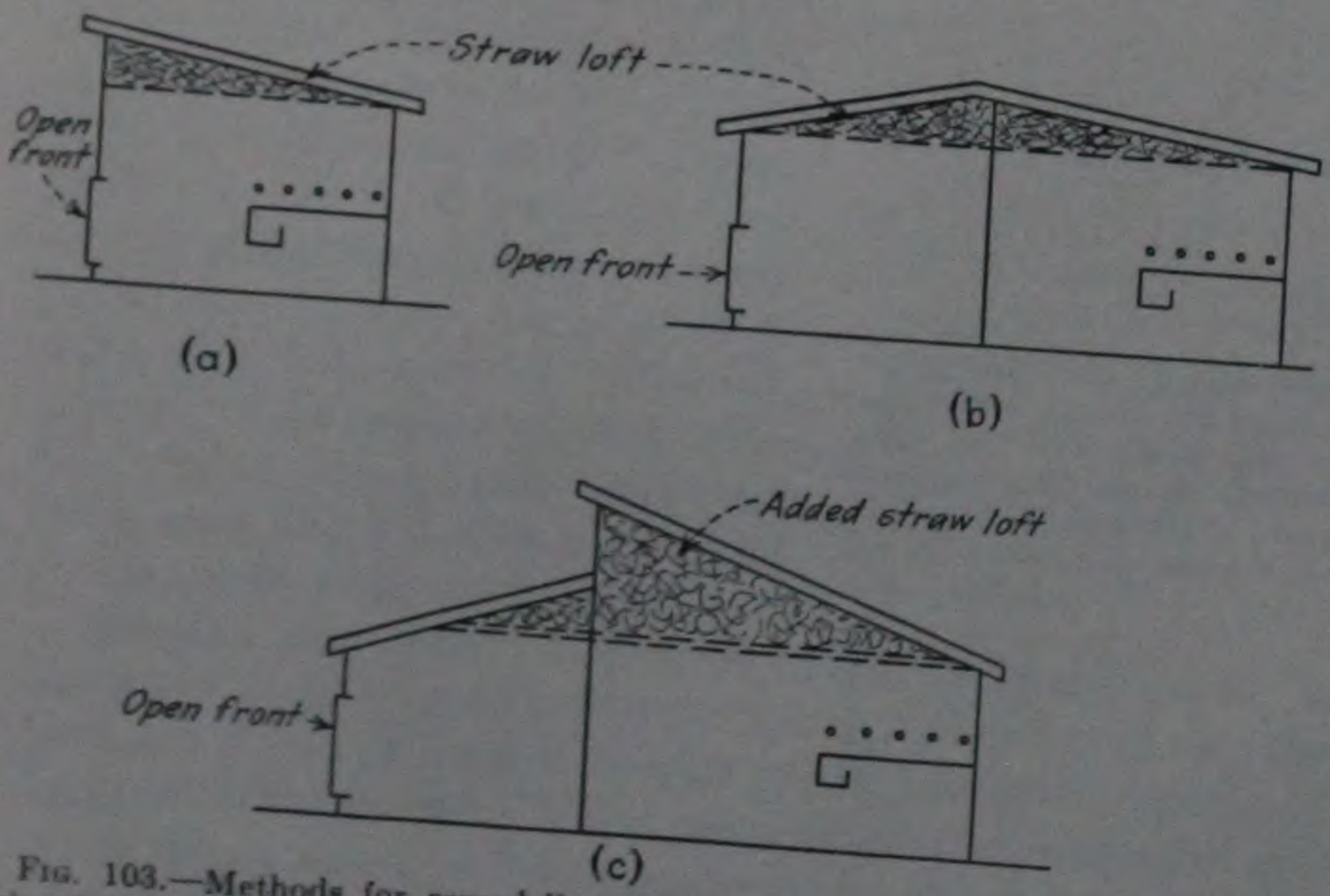


FIG. 103.—Methods for remodeling two common types of poultry houses: (*a*) original house; (*b*) addition on south to increase width; (*c*) half monitor poultry house to which straw loft was added.

Remodeling Poultry Houses.—Poultry houses are often built with little attention to heat conservation, control of drafts, etc., and it is necessary to remodel them to secure best results. In the narrow-shed type with an open front the roosts are usually too close to the open front. Figure 103 shows a satisfactory method for increasing the width where it is desired to use an open-front poultry house.

Problem

117. A farmer has a general-purpose barn built from the plan shown in Fig. 57. He plans to change the barn into a dairy barn. He expects to keep 20 cows, 4 two-year-olds, 4 yearlings, and 4 calves each year. He wants to make the barn complete so far as maternity, calf pens, feed storage, and processing are concerned. Draw the existing floor plan to a scale of $\frac{1}{8}$ in. = 1 ft. Show a revised plan with any additions that you would recommend.

CHAPTER XXVI

BARN FRAMES

152. The pole frame is the simplest type of barn frame. It consists of poles set in the ground at 10- or 12-ft. intervals with girts, braces, and plates nailed to them to form the supporting framework for the structure. No foundation is required, and the amount of bracing needed is greatly reduced so that both material and labor are less than for other types of framing. Inspection of a large number of barns built in this way showed that many of them had settled unevenly, pulling the whole structure out of shape. The uneven settling was caused in most cases by softening of the ground around one of the poles. Since the weight of the structure is carried on the poles and since the ends in the ground are not large, the areas under them can easily be overloaded. In many of the newer structures using this type of frame, treated poles are being used, and a footing is provided for each pole, as shown in Fig. 104.

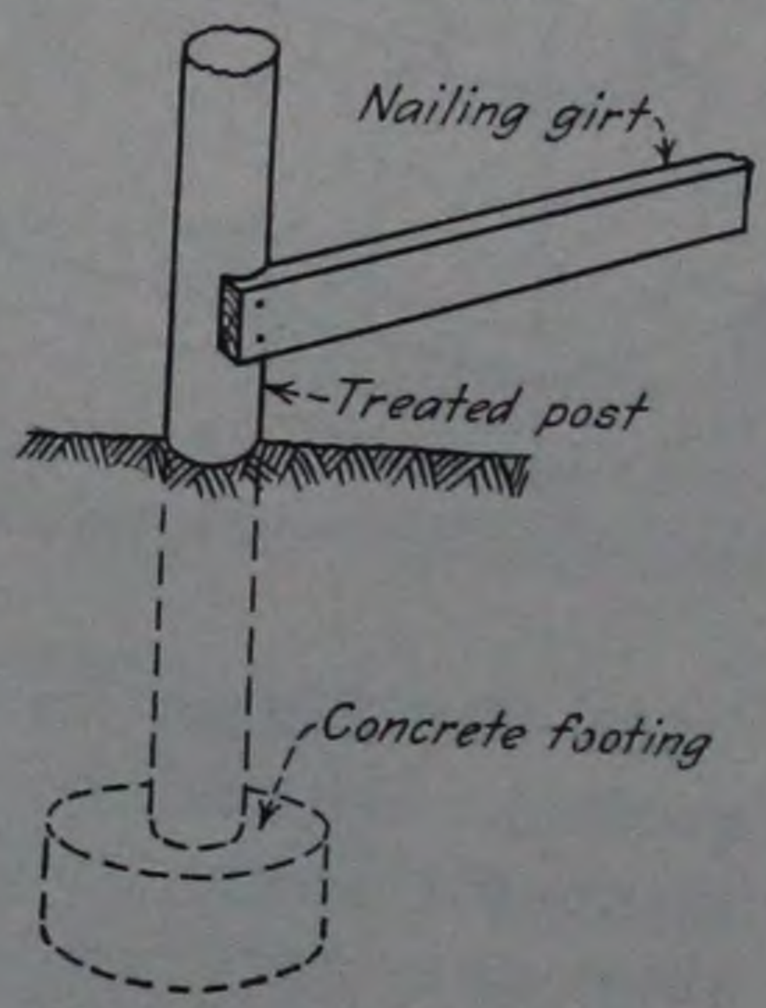


FIG. 104.—Footing for pole-frame barn to prevent uneven settling. The hole is dug to the size and depth desired. Concrete is poured in to a depth of 8 to 12 in. without the use of forms.

153. The post frame, sometimes called the *timber frame,* is similar to the pole frame in many respects. It differs in that the posts are placed on a sill or directly on the foundation instead of being set in the ground. This type of framing is designated as a *rough, hewed, sawed,* or *built-up* post frame, depending upon the kind of posts used. Many of the older barns were built from rough posts just as they came from the timber or were hewed square to facilitate construction. In modern construction the posts are either sawed to the desired size or built up from ordinary

stock lumber. Six-by-sixes are made by spiking three two-by-sixes together; eight-by-eights, by using two-by-eights, etc.

In post-frame barns the posts are placed at 10- or 12-ft. intervals, and since they carry the load the foundation is made larger under them and is often reduced to a thin wall between them (see Fig. 105).

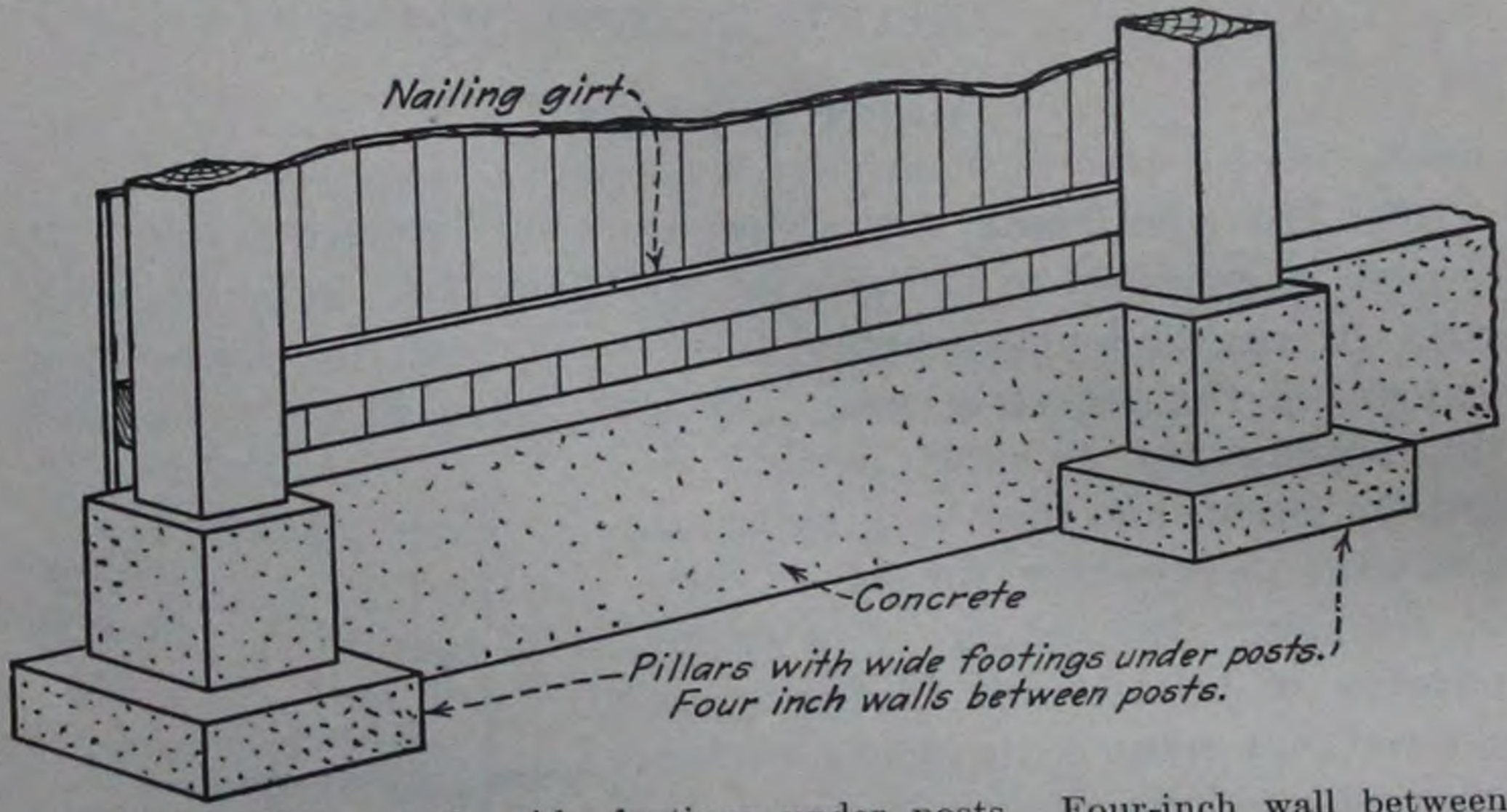


FIG. 105.—Pillars with wide footings under posts. Four-inch wall between pillars.

154. The balloon frame is used when horizontal siding is specified. With this type of frame the weight of the structure is distributed evenly on the foundation by means of studding, which are usually placed at intervals of 2 ft. (see Fig. 106). The foundation, therefore, is best made of uniform thickness and the footings of uniform width. Corner studs and those beside the larger doors are doubled to give them greater strength and stiffness. This type of frame is favored by many because it is easier to erect than the post-frame type, and the foundation, being of uniform width around the building, is less trouble to form. These advantages are often overbalanced, however, by lack of strength and stiffness in the structure as compared to post framing and by the fact that vertical siding cannot be used readily with the balloon frame.

155. Semicircular Roof and Frame.—In the construction of this frame, a laminated member is bent into a semicircle on a radius equal to one-half the width of the desired structure. To increase the strength and improve the appearance of this building,

a ridge board 2 by 12 in., or even larger in some cases, is placed on edge on top of these curved rafters and parallel to the length of the building. Braces are built on either side of the ridge and

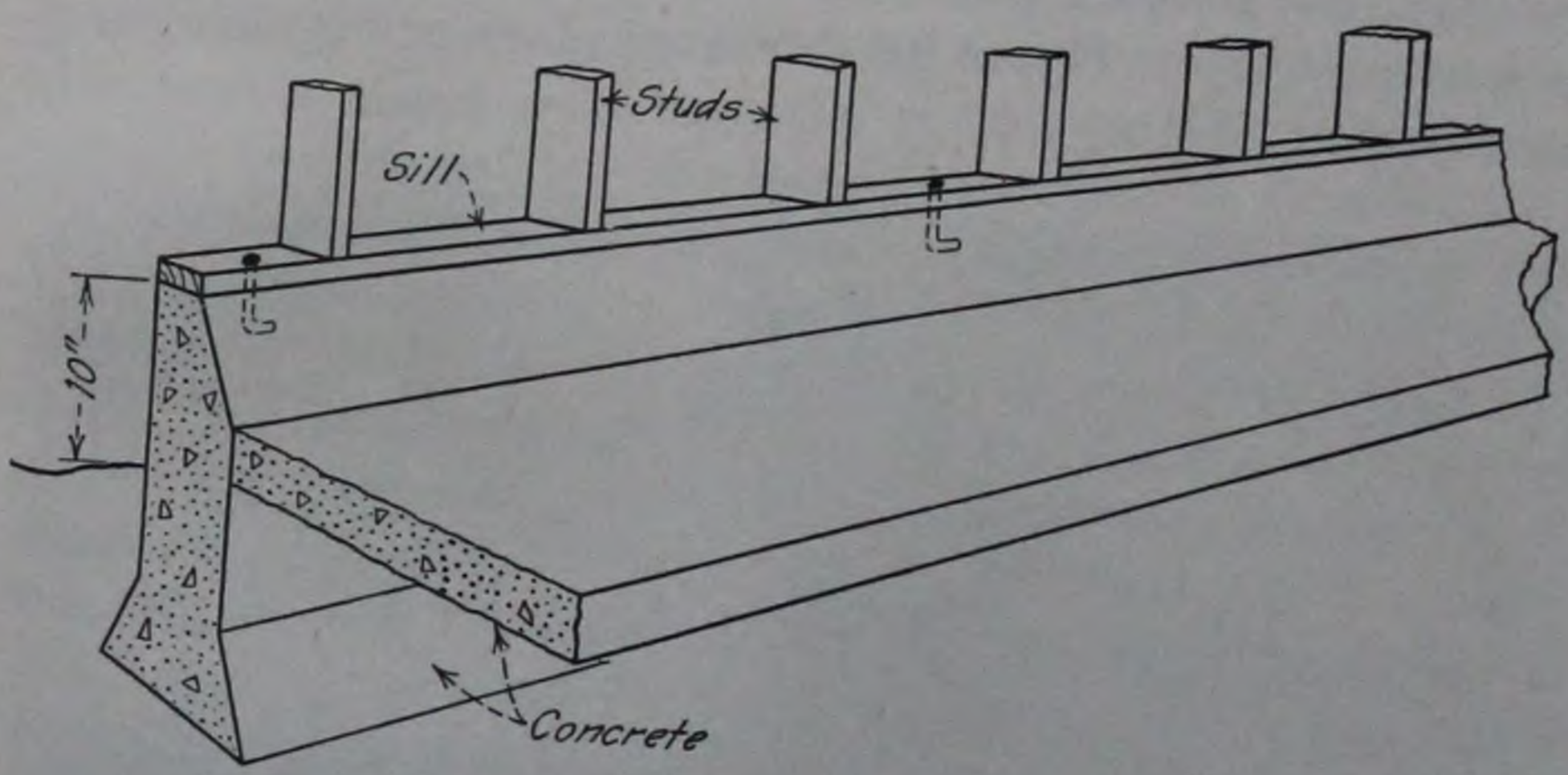


FIG. 106.—Foundation for balloon frame.

made to fit into the general curve of the roof. Wire cable braces, strip sheathing, and galvanized sheets complete the structure. These semicircular frames are built in widths up to 36 ft. and

FIG. 107.—Semicircular roof and frame.

have been used extensively for machinery-storage buildings as well as animal shelters.

156. Steel Frames.—Although steel posts, girders, and equipment are used quite generally in barn construction, the regular

framework has been largely of wood construction. Steel has many advantages in construction, and when the demand has been developed to the point where large-scale production is justified steel framing may be low enough in cost so that it can be used generally. Figure 108 shows one of the new types of steel barn frames.

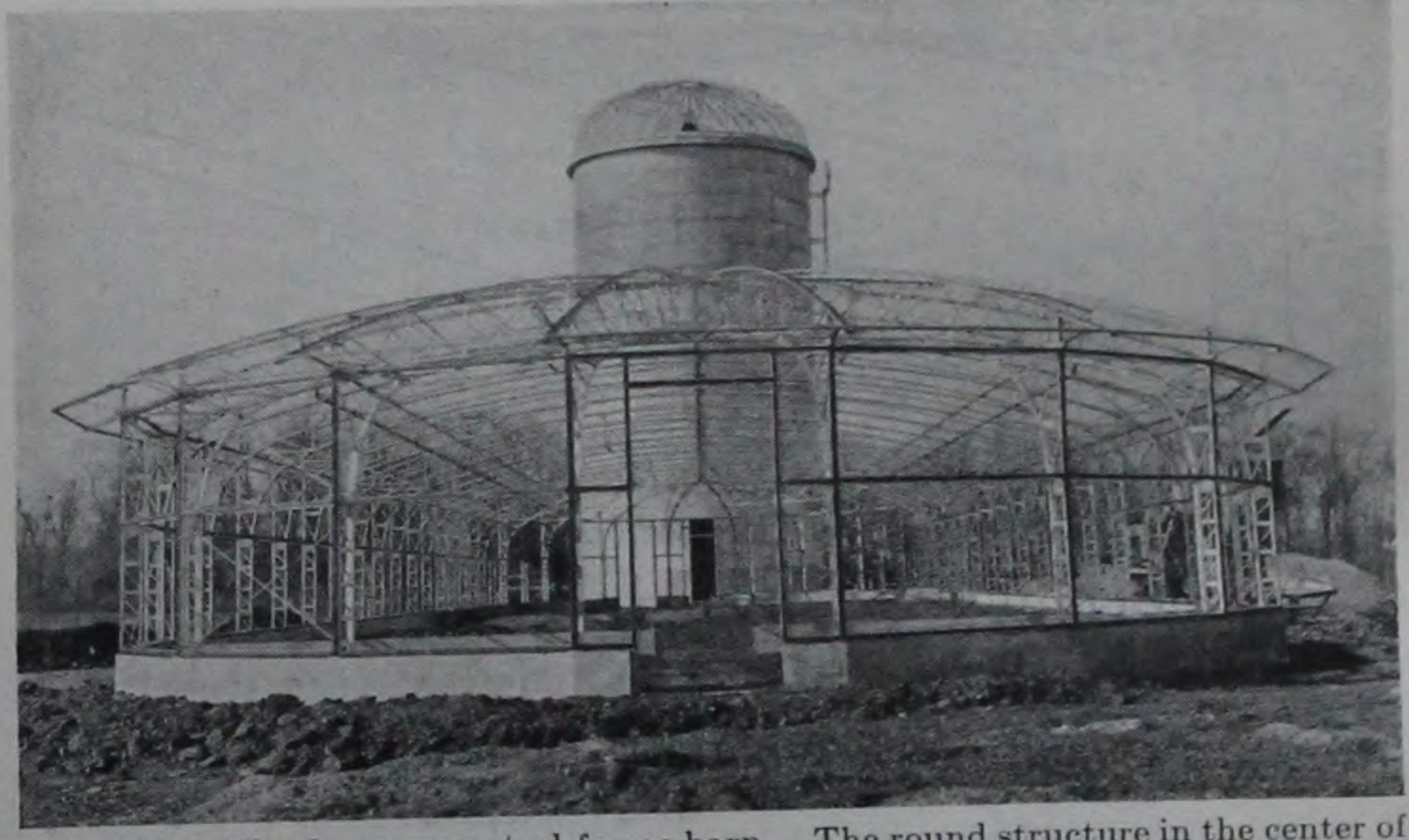


FIG. 108.—The Jamesway steel-frame barn. The round structure in the center of the barn is for hay storage.

157. Masonry Barns.—Building blocks of concrete or tile are being used to build the walls and even the roofs of barns, thus taking the place of the framework. These tile walls carry the loads and side thrust produced by the roof. The stiffness needed in the walls to take care of this side thrust is secured by building pilasters on the outside at intervals of 10 or 12 ft.

158. Foundations.—In foregoing chapters on concrete and tile it was pointed out that these materials would carry safely from 2,000 to 5,000 lb. per square inch in compression. Most farm buildings will not have sufficient weight to load the foundations to the point of failure of the concrete so long as the load is merely one of compression. Foundations do fail, however, and therefore other stresses must be imposed. Inspection of a number of these failures showed that the subsoil under the foundation had failed. This subjected the foundation to stresses other than compression and caused the failure.

These stresses, other than vertical compression, caused the foundations to fail either by tilting outward where there were long straight sections, by settling or splitting at the corners, or by breaking in a vertical line at some distance from the corner of the building. In many barns the earth floor inside the foundation is at a higher level than the ground outside. Manure is allowed to accumulate, increasing this difference in elevation. This, together with continual tramping of the ground inside the barn and the occasional crowding of the wall by livestock, contributes to the tendency to push the wall outward at the top. Wider footings, reinforcement properly placed, or pilasters or bracing walls may be used to counteract this tendency and prevent failure from this cause. The soil outside the barn becomes thoroughly saturated many times when that inside the wall is dry. This decreases the bearing power of the soil under the outside edge of the footing and may also be a contributing factor to many failures. Adding eavestroughs and downspouts to barns and providing drains for the water collected or the installation of underdrains or diverting ditches may be necessary in some instances to prevent this trouble.

Where corners break open through pressure on the two walls, it is evident that there is need for reinforcement in the corner to resist the tension produced. Where corners have settled and the foundation has broken a few feet back along the wall, there is evidence of a need for a larger footing or for reinforcing to strengthen the foundation as a cantilever beam. Reinforcement near the top of the wall to force the side walls to assist in carrying the load, extended around the corner to prevent splitting of the foundation at this point, will forestall such failures.

159. The bearing power of soils depends on their texture and moisture content. Since the amount of moisture may be increased at any time, it is well to use values for moist soil in making computations (see Table 36).

160. Footings of the proper size and design are a very important factor in securing a good building. To figure the size of footing needed it is necessary to know the load to be applied to it. Then, by reference to the table on bearing power of soils, the proper unit can be selected and the size of footing computed. Footings should be placed below the frost line and should be made with a level face in contact with the soil. In constructing a footing, a

TABLE 36.—BEARING POWER OF SOILS

Material	Pounds per Square Inch
Dry clay in thick beds	70
Moist clay	42
Wet clay	20
Dry sand	30
Dry soil	40

trench is dug to the width needed and concrete for the footing poured. Forms should then be set both inside and out and the foundation wall poured in place on the footing. In this procedure water is not absorbed from the concrete so readily as it is when the concrete is poured in a trench, as in Fig. 109*a* and *b*, and the concrete will therefore be of better quality. Reinforcement in

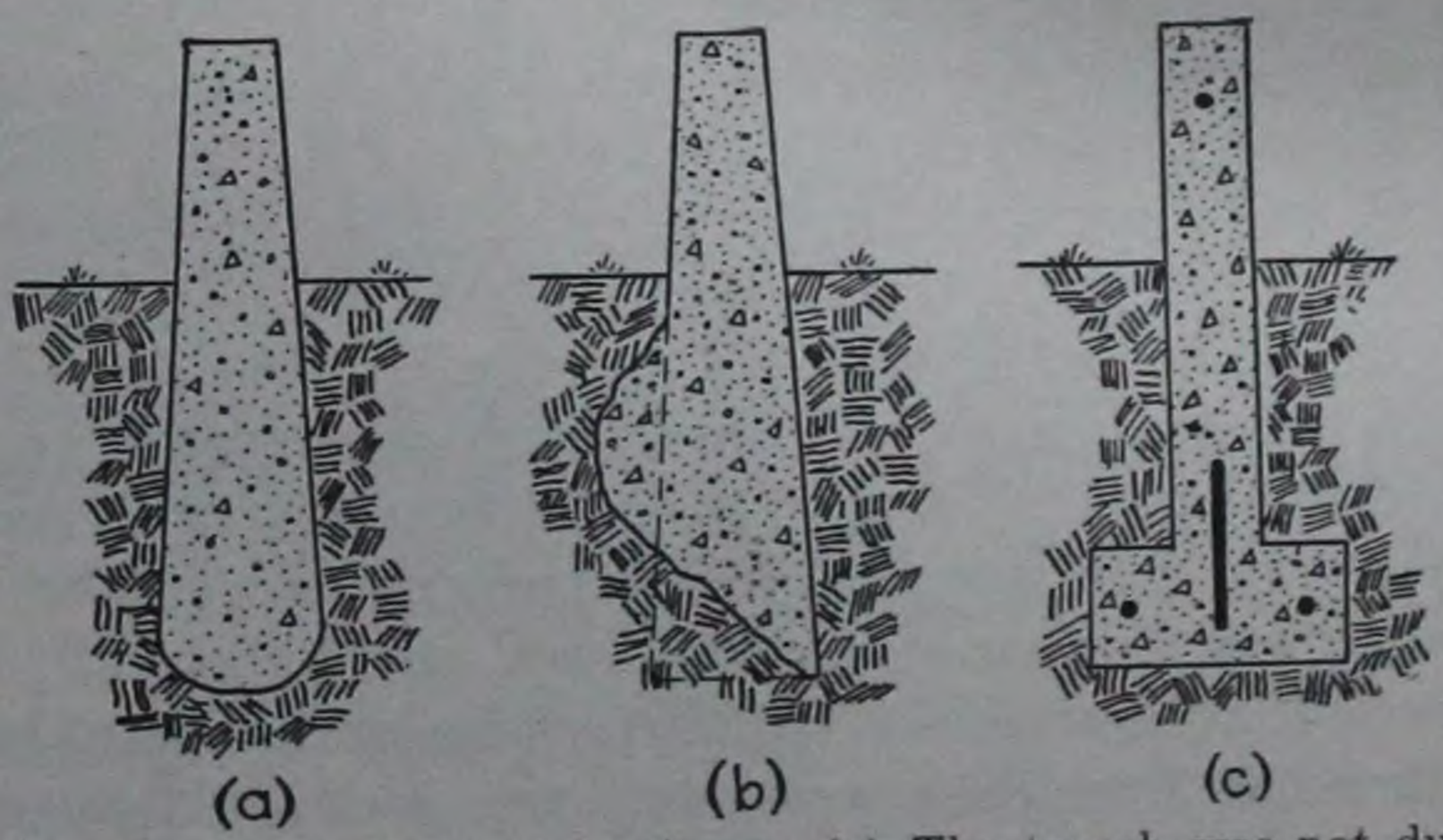


FIG. 109.—Sectional views of footings. (*a*) The trench was not dug to the proper shape and the rounded corners make it possible for the soil to move out from under the footing when the load is applied. (*b*) The earth walls of the trench caved in before the concrete was poured, leaving a wedge-shaped footing. This footing would not carry much of a load, and would be sure to move to one side when the load was applied. (*c*) A reinforced footing which has been constructed in the proper manner.

both footings and foundation wall in well worth while (see Fig. 109*c*). A more complete discussion of reinforcement may be found in Art. 121.

161. The plate used in a post-frame barn is called a *box plate* (see Fig. 110). It is made up with one or more members placed in a vertical position and one or more placed in a horizontal position. This type is used with the pole and the post frame, because the plate must support the vertical load of the roof as

well as the side thrust between posts. The vertical members in the plate are designed to carry the load of the roof and the horizontal members the side thrust.

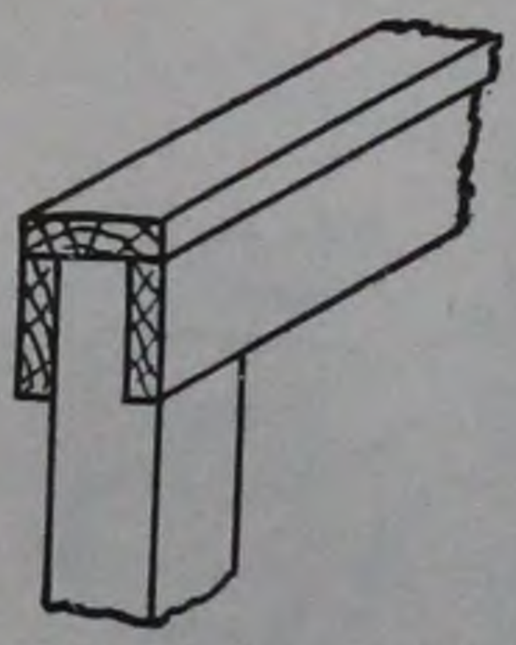


FIG. 110.—Box plate for pole- and post-frame barns.

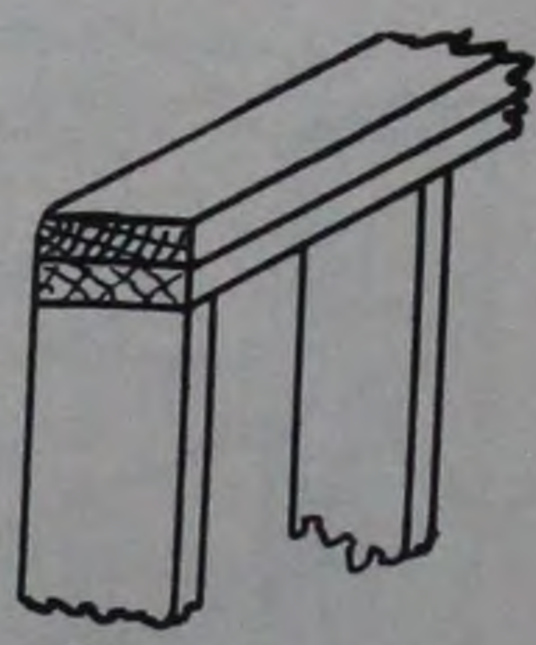


FIG. 111.—Plate for balloon-frame barn.

In the balloon frame each rafter is placed directly above a stud, and thus the plate does not carry the roof load. The outward thrust of the roof must be counteracted, and the plate is

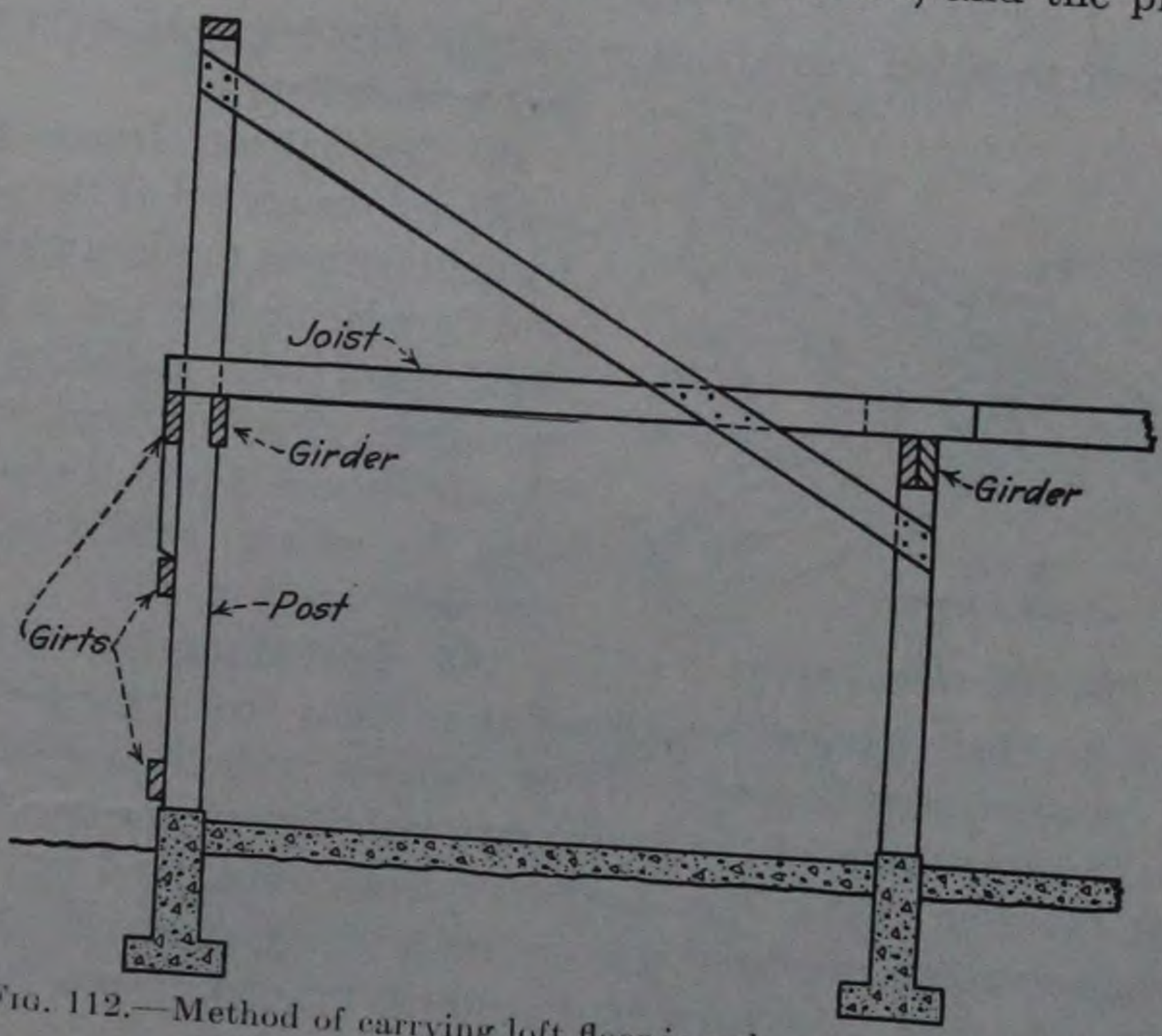


FIG. 112.—Method of carrying loft floor in pole- or post-frame barns.

designed to meet this stress. Members are placed horizontally, as shown in Fig. 111. In long barns the plate is sometimes trussed, similar to the end bracing shown in Fig. 116*a*.

162. Loft Floor Support.—In the pole and post frames it is necessary to support the joists between side wall posts by a girder fastened to these posts (see Fig. 112). The posts in the

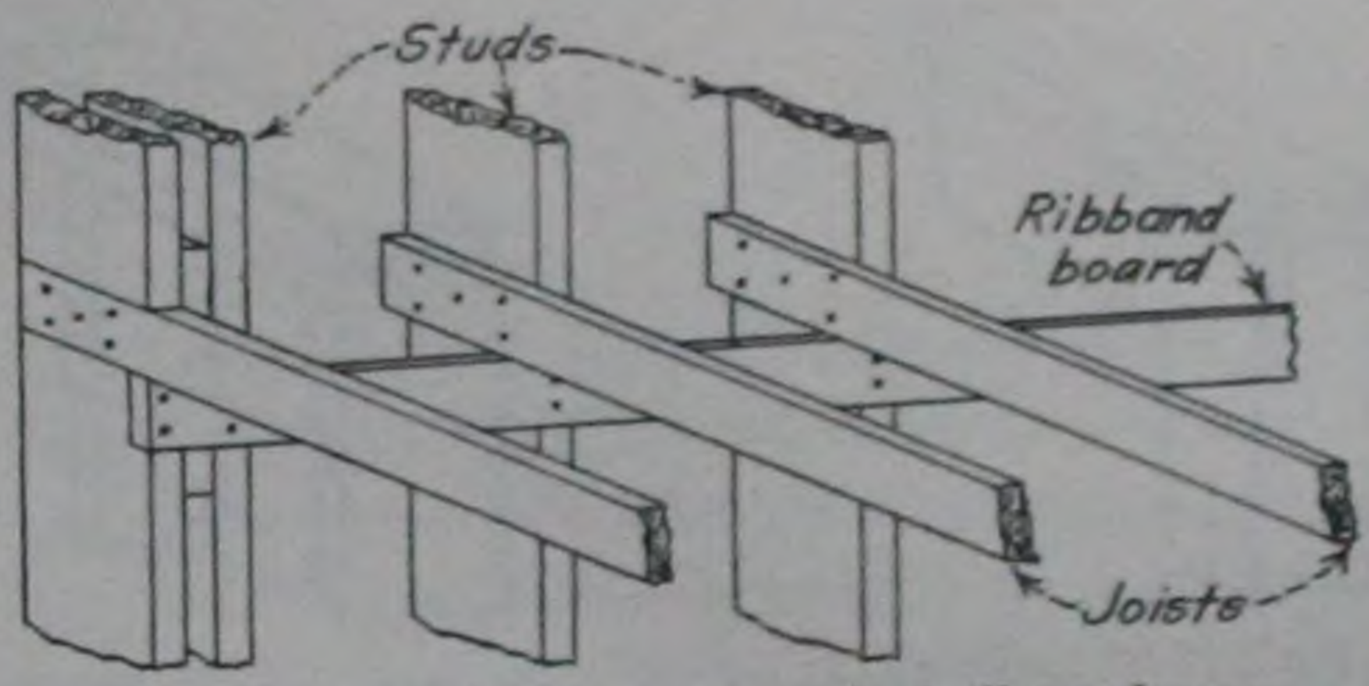


FIG. 113.—End joist support in balloon frames.

center of the barn are cut to the proper length to fit directly under the girder. Splices in joists must always be made over these girders. Steel posts and girders are used in many barns today. They take up less space to provide equal strength, as compared to wood construction, which is often an important factor in design.

In the balloon frame the joists are supported at the wall by nailing them to the studding and by placing them on a ribband board that is nailed to the studding. The ribband may also be recessed into the studding to secure additional strength (see Fig. 113).

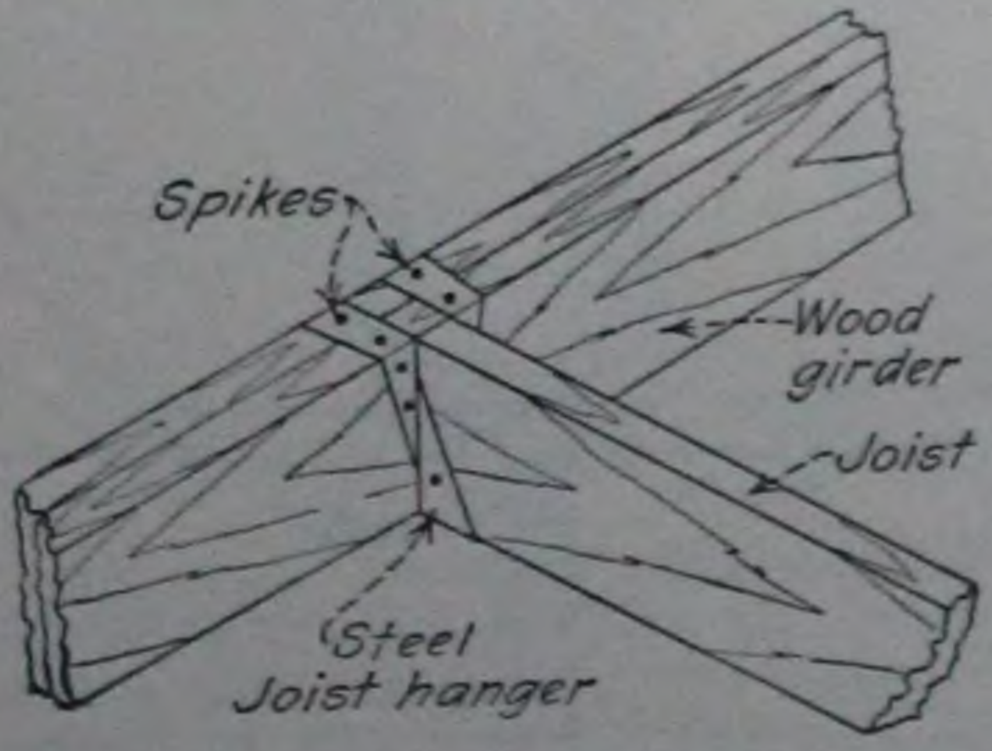


FIG. 114.—Joist hangers.

163. Joist Hangers.—Where it is desirable to have a smooth ceiling without projecting girders, joist hangers may be used. These hangers make it possible to place the lower edge of the joists even with the lower edge of the girder (see Fig. 114). This makes a smooth ceiling and makes it possible to route overhead carriers without interference. Some additional space is secured in the mow, making it possible to reduce the height of the side walls of the structure.

164. Bracing is essential to secure rigidity in a barn frame when it is subjected to loads of different kinds. Different methods are shown in Figs. 115 and 116. The outward thrust of the roof on

side walls must be met by use of ties and braces. Wind loads also produce stresses that must be met by proper bracing. Walls may be braced by fitting pieces between studding, the

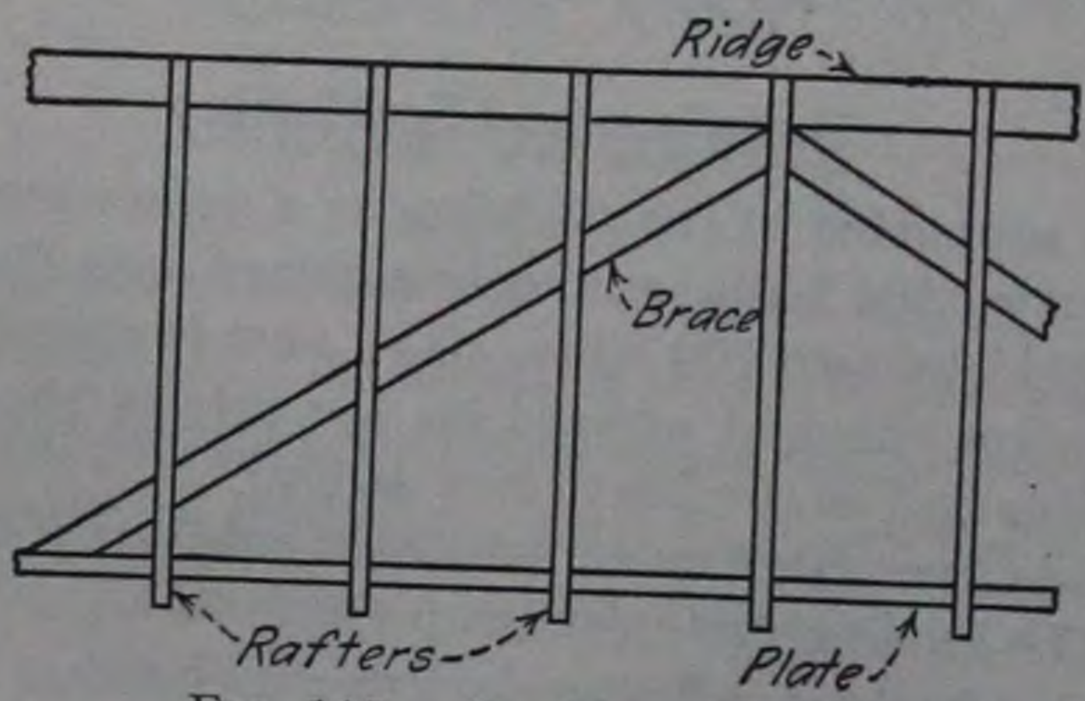
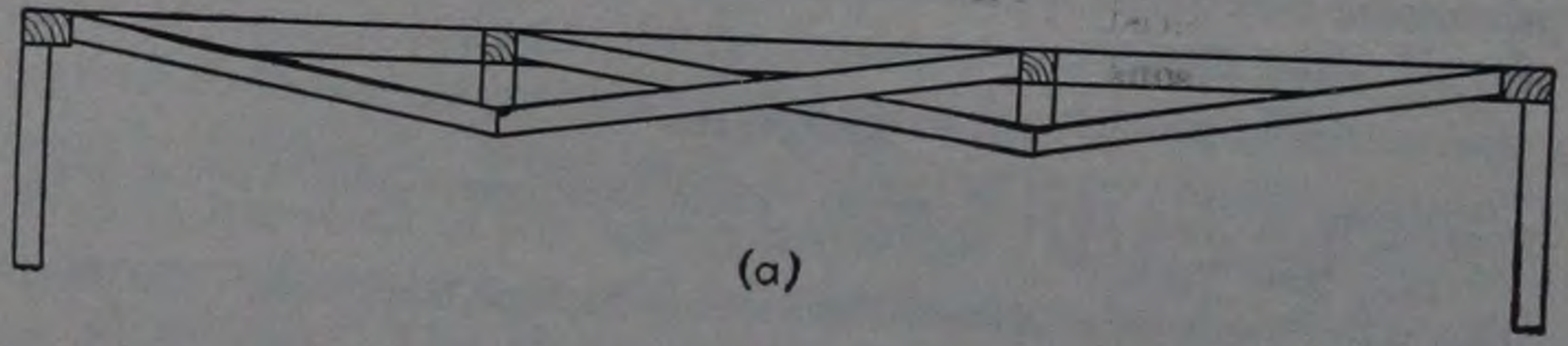


FIG. 115.—Roof bracing.

whole group to extend diagonally from sill to plate; or bracing may be nailed inside studding to fulfill the same purpose. The rafters need bracing to prevent end sway. This bracing may



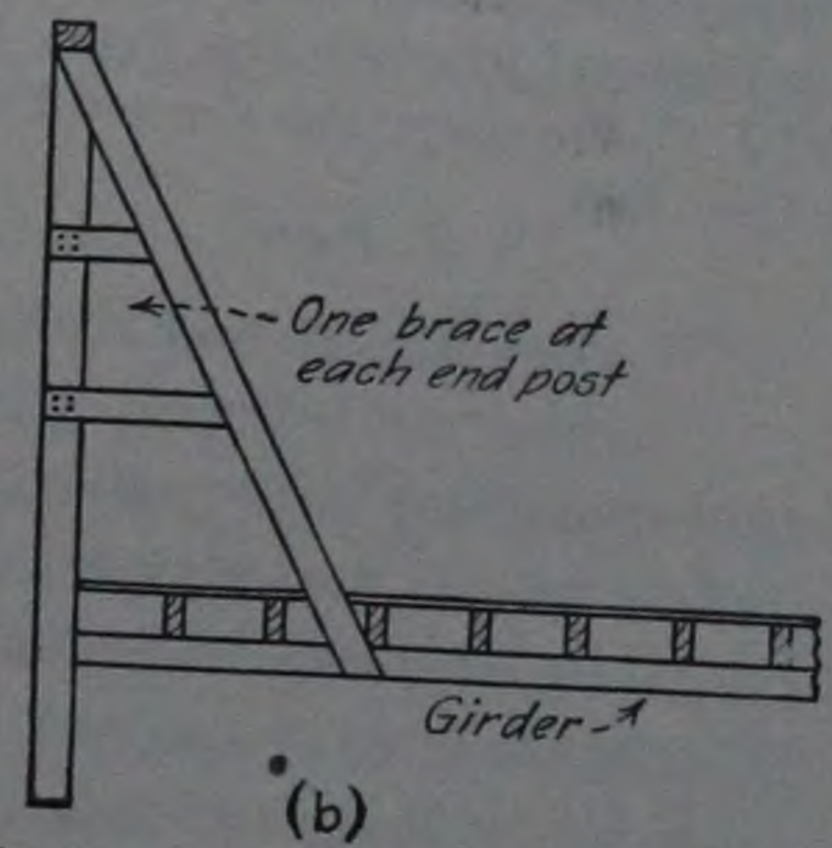


FIG. 116.—End bracing for barns. (*a*) Side view of a horizontal truss. A shelf bracket is placed under each joint to prevent hay loads from pulling bracing out of line. (*b*) Vertical truss built up from girder.

be secured by nailing diagonal pieces under the rafters as shown in Fig. 115. The end walls in a barn usually need bracing, especially above the mow floor. This may be done by building

a horizontal truss to be fastened to the structure at the plate line (see Fig. 116*a*).

In the pole- and post-frame types a vertical brace may be built between the post and the girder as shown in Fig. 116*b*.

Questions and Problems

118. A joist is supported at the studding by a yellow pine 1 by 4 ribband held in place by two 10d nails, recessed or gained into the studding ½ in. The ribband is held by two 10d nails. The joist is spiked to the studding with two 20d spikes clinched upward on the side of the studding. How much load will this end of the joist carry safely?

119. A 6- by 6-in. post is set on an 8- by 8-in. concrete pier having a footing 16 by 16 in. The footing rests on damp clay.

(*a*) How much of a load will this footing support?

(*b*) How much would the 8- by 8-in. concrete pier carry if it is average concrete?

120. A post in the center of a barn must carry a load of 24,000 lb. The footing will rest on wet clay soil. How large should it be?

121. A farmer wishes to reinforce a barn foundation using three ⅝-in. reinforcing rods placed horizontally. How would you suggest that these be placed? Give reasons.

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CHAPTER XXVII

DESIGN OF BEAMS

Farm buildings are used for the storage of hay, grain, and other materials, as well as for the housing of livestock and machinery and must be designed to carry these loads with safety. Common practice in the past in building barns has provided for loose-hay storage overhead. The development of elevating and processing machinery has caused a greater tendency for overhead storage of cut hay and concentrates. This increases the need for a knowledge of stresses produced and the designs required to meet them.

165. Loads.—Snow loads, as well as wind loads, must be reckoned with as forces that produce definite strains in different parts of farm buildings. Snow loads on flat roofs may be as high as 30 lb. per square foot but have a decreasing effect as the pitch is increased. Wind loads, on the contrary, have a greater effect as the pitch of the roof is increased. Many designers use 30 lb. per square foot as safe for combined snow and wind loads on all pitches. The relation between wind velocities and the resulting pressure on vertical walls may be expressed by the formula

$$P = 0.004 \times V^2 \qquad (27)$$

where P = load in pounds per square foot.

V = wind velocity in miles per hour.

In dealing with roof trusses, such pressures may be positive on the windward side and negative on the lee side.

To determine the amount of stress to which a beam or column will be subjected, it is necessary to determine the kind of load, its amount in pounds, and the method of its application. So far as farm buildings are concerned, loads are either *concentrated*—that is, applied at one or more points—or *distributed uniformly* over the member. Most loads in farm buildings are uniformly distributed loads. For example, hay in a mow is distributed uniformly over the full length of the joists, girders, etc. Grain in bins is also an example of uniformly distributed loads.

The total load on any beam or column consists of the weight of the structure itself, which is called a *dead load*, and the weight of the materials stored, which is called a *live load*. In a concrete beam, for example, the dead load is large and plays a very important part in the design; in timber construction this load is not so important but is still of sufficient importance to be considered, especially on spans greater than 10 ft. Live loads are those to be considered with the occupancy of the building, whether they come from storage of hay, grain, or livestock. Live loads that are applied with an impact or vibration (such as livestock, running machines, trucks and wagons, etc.) are considered to have double the magnitude of the same load applied without impact. The impact produced would, of course, depend on the distance through which the object fell, but the rule applies to common loads in farm buildings. Wheat is added to a bin, corn to a crib, and even hay to a mow in relatively small quantities and are not considered as being applied with impact. Hay is dropped in ½-ton bunches from the carrier in the top of the barn, but its fall is effectively broken by the air cushion formed under the falling hay, and it is considered to be a load applied without impact.

A list of the more common materials stored and their weights per cubic foot is given in Table 37.

The loads in farm buildings are sometimes rather large. The ordinary farm barn may hold from 75 to 100 tons of hay. This weight acts as a system of forces tending to bend the supporting joists and girders. So long as these forces are held in equilibrium there must be a reaction or resisting moment set up in each beam of equal and opposite effect to the force applied. Any internal resisting force is called a *stress*. Stresses are *compressive*, *tensile*, or *shear*, either singly or in combination, depending on the manner in which the retaining unit is stressed. A column or post carrying the mow floor in a barn is subjected primarily to a compressive stress; a wire holding a weight, to a tensile stress; the drive shaft in a car, to a torsional or twisting stress; a joist or girder supporting hay in a mow, to a bending stress, and a rivet holding a double lap joint, to a shearing stress.

166. Bending Moment.—In the design of beams and girders, it is necessary to know the amount of the stress that is produced in the beam or girder by the load in order to be able to select

a structural member that will meet it safely. The "moment" or turning tendency of any force about any point is the product

TABLE 37.—WEIGHTS OF VARIOUS MATERIALS

Material	Weight, pounds per cubic foot
Hay, loose	4
Hay, baled	12
Hay, cut	10
Straw, loose	3½
Straw, baled	9½
Corn, ear	28
Corn, shelled	47
Wheat	48
Oats	27
Barley	40
Cottonseed meal	40
Apples	40
Coal	50
Concrete	150
Ice	58
Sand	100
Limestone, solid	165
Limestone, ground	82
Brickwork	125
Cobblestones	150
Snow, fresh fallen	8
Gasoline	42
Oil, lubricating	57
Granite	172
Flint	165
Sandstone	147
Cotton, in bales	30
Wool, in bales compressed	48
Wool, in bales not compressed	13
Molasses, in barrels	48
Tobacco, in bales	35

Material	Weight, pounds per square foot
Wood shingles	2
Slate shingles	4.5
Corrugated iron	2.25
Asbestos shingles	4.5
Asphalt roofing	2.5
Tile roofing	18

Material	Weight, pounds per board feet
Cedar	3
Hemlock	2.1
Cypress	3.1
Douglas fir	2.7
Oak	4.1
Shortleaf pine	2.6
Pine sheathing	3
Georgia yellow pine	3.2
White pine	2.3
Redwood	2.5
Hickory	4.0
Elm	3
Walnut	3.3
Ash	3.4

of the force times the shortest distance from its line of action (lever arm) to the point in question. The algebraic sum of the moments of all the applied forces acting on a beam to the right

or left of a given section is called the *bending moment* at that section. The amount of the stress is dependent on the type of beam, its length, and the type of load.

167. Types of Beams.—Beams are divided into three classes, *cantilever*, *simple*, and *continuous*. A *cantilever beam* is one that is rigidly supported at one end (see Fig. 117). The greatest fiber stress would occur in the beam at the point where it is fastened into the wall. For a concentrated load applied at the unsupported end, the bending moment in inch-pounds would be equal to the load in pounds multiplied by the length of the beam in

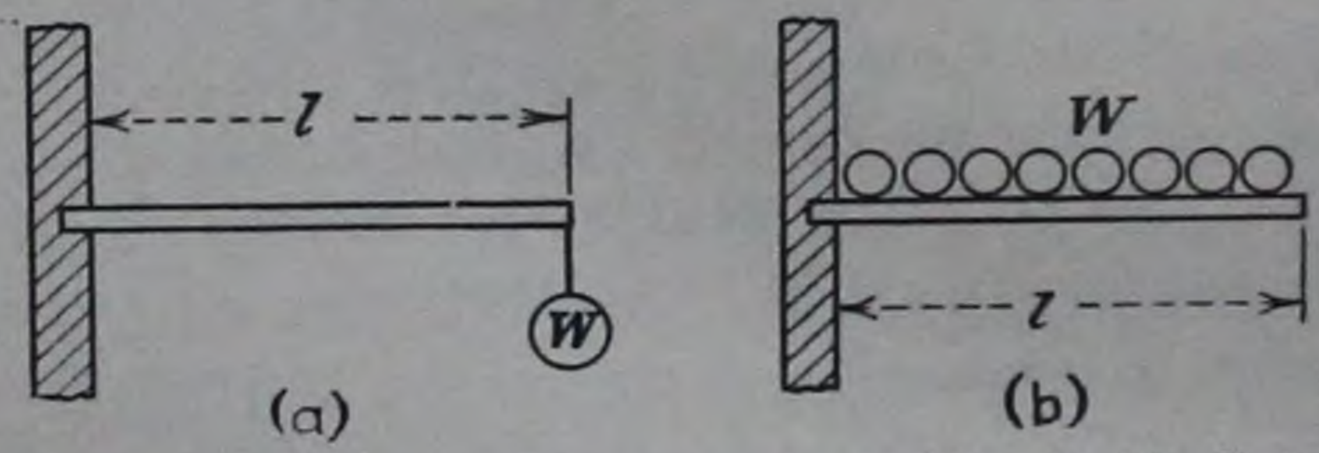


FIG. 117.—Cantilever beams: (*a*) concentrated load; (*b*) distributed load.

inches. Expressed as a formula, the bending moment of a cantilever beam with a concentrated load is

$$BM = WL \tag{28}$$

where W = load in pounds.
L = length of beam in inches.

In the case of a uniformly distributed load on a cantilever beam

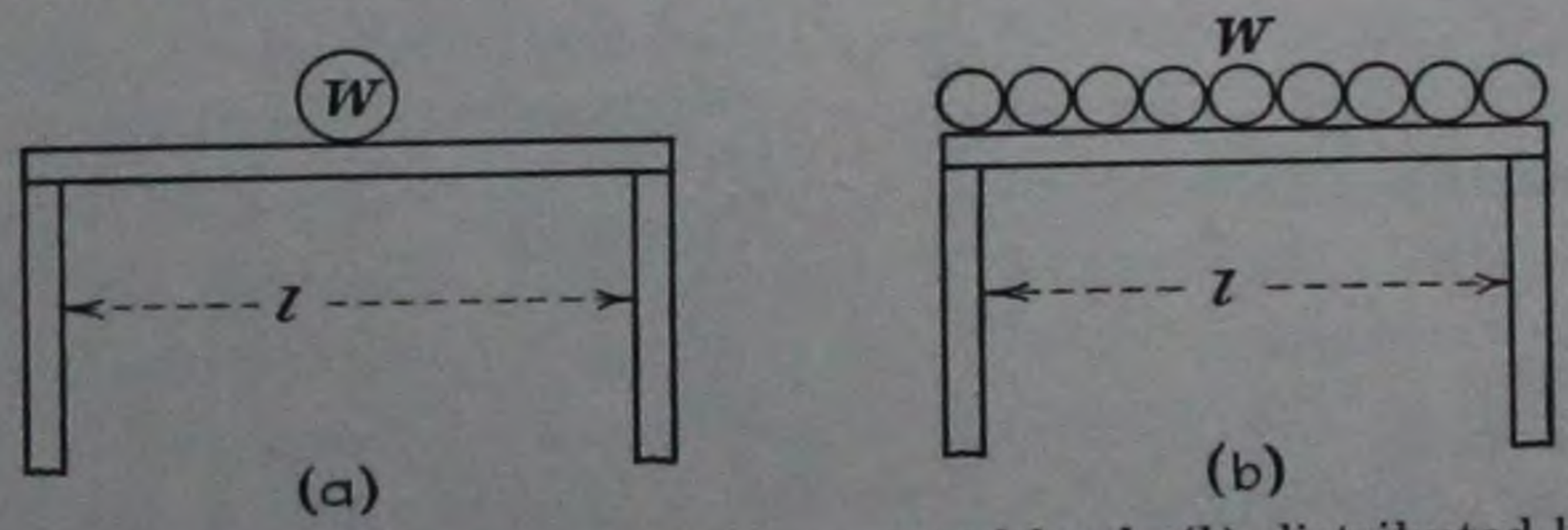


FIG. 118.—Simple beams: (*a*) concentrated load; (*b*) distributed load.

(Fig. 117*b*), the formula for bending moment is

$$BM = \tfrac{1}{2}WL \tag{29}$$

A *simple beam* is one that is freely supported at both ends (see Fig. 118). If it has a concentrated load applied at the center, the bending moment is computed by substituting in the formula

$$BM = \tfrac{1}{4}WL \tag{30}$$

If the load is uniformly distributed, as is usually true in the case

of hay, corn, or oats in storage, the formula for bending moment is

$$BM = \tfrac{1}{8}WL \tag{31}$$

A *continuous beam* is one that is supported at various points along its length (see Fig. 119). In most barns the girder is a built-up member that extends the full length of the barn and is supported at various intervals by posts. This is a good example of a continuous beam. In this form of beam the bending moment

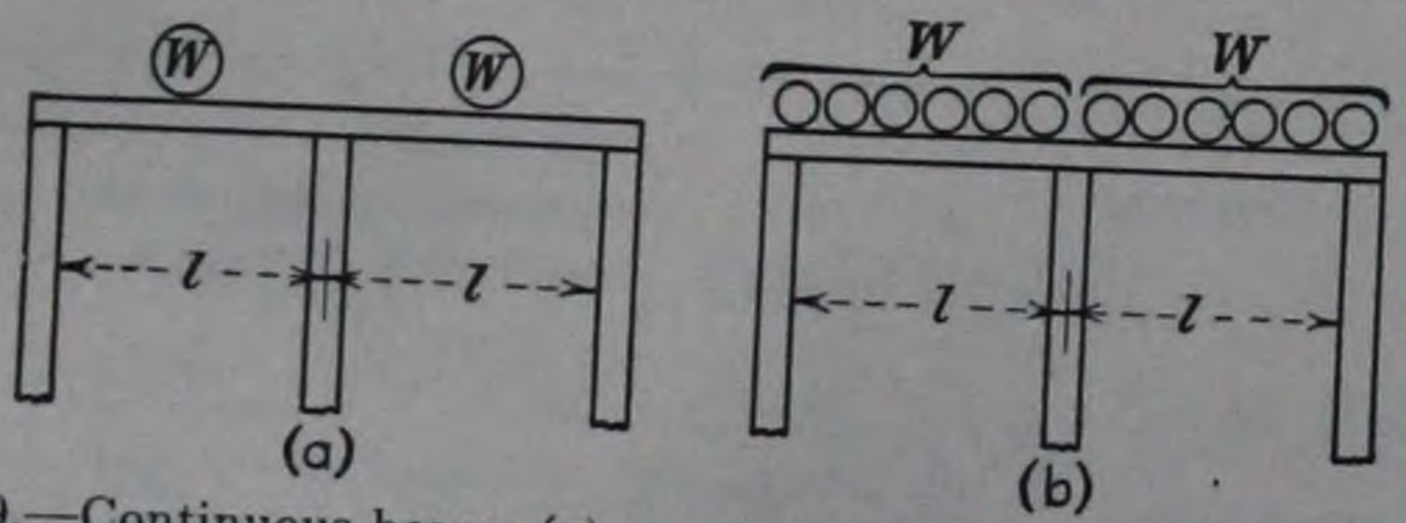


FIG. 119.—Continuous beam: (*a*) concentrated load; (*b*) distributed load.

is reduced because one load tends to balance another over the supporting posts. The greatest bending moment, therefore, is not in the center of the span but is shifted to points nearer the supports. With loads concentrated at the center of each span,

$$BM = \tfrac{1}{6}WL \tag{32}$$

where W = load in pounds on each span.
L = length of each span in inches.
With uniformly distributed loads

$$BM = \tfrac{1}{12}WL \tag{33}$$

168. Computation for Size of Beams.—After determining the bending moment produced by a load, the next step is to select the material, and determine the shape and size of beam needed. Different materials have different strengths, and this fact will, of course, influence the design. Table 38 gives a number of the more common materials used in farm buildings and the safe fiber stress per square inch of each.

The *factor of safety* is the ratio between the load required to cause failure and the working load that is to be applied to the member in everyday use. Wood is of such variable quality that a factor of safety of six is used. For example, the maximum strength in bending within the elastic limit for shortleaf yellow pine and within the limit of deflection for the beam is about 6,600 lb. per square inch, but only one-sixth of this amount, 1,100 lb.

per square inch, is considered as a safe load in computations for strength of beams. Steel, being more uniform, may be used with a factor of safety of four.

If the amount of the load in pounds, its manner of application (concentrated or distributed), the kind of load (dead or live, with or without impact) and the kind of beam (cantilever, simple, or

TABLE 38.—STRENGTH OF MATERIALS*

Kind of material	Safe fiber stress, pounds per square inch†			
	In bending	In compression with the grain	Across the grain	Shear, parallel to grain
Longleaf yellow pine	1,300	1,300	260	180
Shortleaf yellow pine	1,100	1,100	170	170
White pine	900	1,000	150	100
Hemlock (Western)	1,100	1,200	220	160
Oak (white)	1,100	1,300	450	210
Cypress	900	1,100	170	120
Douglas fir	1,200	1,200	310	196
Steel	15,000	15,000	15,000	

* From O'ROURKE, C. E., "General Engineering Handbook," McGraw-Hill Book Company, Inc.

† Computed on a basis of a factor of safety of 6 (except steel which is 4).

continuous) are known, the bending moment produced can be computed. Table 38 gives the safe fiber stress in bending for the material specified. Dividing the bending moment (BM) by the safe fiber stress (sfs) for the material gives a figure from which the size and shape of beam can be determined. This term is called the section modulus (SM). The above relationship is expressed by the formula

$$\frac{BM}{sfs} = SM \tag{34}$$

The formula for the section modulus of a rectangular beam is

$$SM = \tfrac{1}{6}bd^2 \tag{35}$$

where b = breadth of the beam in inches.
d = depth of the beam in inches.

Since $BM/sfs = SM$ and $\frac{1}{6}bd^2 = SM$, it follows that

$$\frac{BM}{sfs} = \frac{1}{6}bd^2 \tag{36}$$

Example: A mow floor is to be designed to carry baled hay to a depth of 9 ft. Joists 12 ft. long are spaced 2 ft. on centers. Douglas fir lumber is to be used. What size will be needed for the joists? *Solution:* This is a live load without impact, uniformly distributed. Each joist will carry $12 \times 2 \times 9 = 216$ cu. ft. of hay weighing 12 lb. per cubic foot (see Table 37), or 2,592 lb. The joists are supported at each end, forming a simple beam. Referring to formula (31), the bending moment produced is

$$BM = \tfrac{1}{8} \times 2{,}592 \times 12 \times 12 = 46{,}656 \text{ in.-lb.}$$

Referring to Table 38, the safe fiber stress in bending for Douglas fir is 1,200 lb. per square inch.

$$\frac{46{,}656}{1{,}200} = 38.88, \text{ the } SM \text{ required}$$

From formula (35), $SM = \tfrac{1}{6}bd^2$, or 38.88. Assuming that 2-in. stock will be used, substitute $b = 2$ in., and solve for d.

$$38.88 = \tfrac{1}{6} \times 2 \text{ in.} \times d^2 \qquad \text{or} \qquad d = \sqrt{38.88 \times 3} = 10.8 \text{ in.}$$

If the material is entirely free from defects and sawed full size, a 2 by 10 would usually be used; but if it does not meet these requirements the next larger stock size, a 2 by 12, should be used. It might be found advisable to change the spacing for the joists to 1 ft. on centers and figure the size of joists needed for this spacing. This would, of course, require less depth in the joists and would reduce the amount of vertical space taken by the joists in the structure.

169. Shear.—Short wood beams carrying heavy loads may fail from *shear*, the slipping of the fibers of the wood on each other. No trouble is encountered with vertical shear unless the bearing surfaces are too small. To determine the horizontal shear in a beam, multiply the load in pounds applied to the beam by the constant 0.75, and divide this product by the cross-sectional area of the beam in square inches.

$$S = 0.75 \frac{W}{bd} \tag{37}$$

where S = horizontal shearing stress created by load on beam.
W = total load on beam in pounds.
b = breadth of beam in inches.
d = depth of the beam in inches.

Check this against the safe stress in shear for the material (see Table 38). If the beam will fail in shear, larger stock must be used.

For example, apply the test for shear to the problem just discussed. In this problem the load was 2,592 lb. The breadth

and depth of the beam were 2 and 10 in., respectively. Substituting in the formula for shear,

$$S = 0.75 \times \frac{2{,}592}{2 \times 10} = 97.2 \text{ lb. per square inch.}$$

By consulting Table 38, the allowable stress in shear for Douglas fir is found to be 196 lb. per square inch. The 2 × 10 joist of this material would, therefore, be safe from failure by horizontal shear.

170. Crushing across the Grain.—A beam or joist may be sufficiently strong in bending, safe with respect to horizontal shear, and still not be successful in use, because of crushing of the material or vertical shear at the point of support. To determine this crushing effect, the area of contact should be computed; this, multiplied by the safe fiber stress for the wood in compression across the grain, gives the safe load that can be applied, considering only this one aspect of the design. For example, in the problem used in illustrating the computation for bending moment, and again for shear, the load carried by one end of the beam was 1,296 lb. (half of the total load on this simple beam). Assuming that this joist rests on an I-beam with a 4-in. top width, the area of contact between the joist and the I-beam would be 2 × 4 = 8 sq. in. Referring to Table 38, the safe load for Douglas fir in compression across the grain in 310 lb. per square inch. Multiplying 310 by 8 gives 2,480 lb., the safe load so far as crushing of the material is concerned. Since this safe load is larger than the load to be applied, the design is satisfactory.

171. Steel beams are being used extensively in buildings where long spans are needed and where headroom is a factor. The largest use is for girders, although use of steel beams for joists is increasing. Among all the shapes available in steel beams, the I-beam is most useful in farm building work. The formula for modulus of section of steel I-beam is beyond the scope of this book; therefore a table giving the section modulus of some of the more common sizes and weights is used (see Table 39).

To determine the size of I-beam that will be needed, the procedure is the same as for rectangular wood beams. For purposes of illustration, let it be desired to determine the size of I-beam required for the conditions in the previous problem illustrating the selection of wood beams. Since the section modulus

for I-beams is given, formula (34) applies. The *sfs* for steel is 15,000 lb. per square inch. Substituting in the formula $BM/sfs = SM$, we have $46{,}656/15{,}000 = 3.11$, the SM required. By referring to Table 39, it is seen that a 4-in. I-beam weighing 8.50 lb. per foot could be used satisfactorily.

TABLE 39.—MODULUS OF SECTION OF STEEL I-BEAMS*

Depth of beam, in.	Weight per foot, pounds	Section modulus	Depth of beam, in.	Weight per foot, pounds	Section modulus
3	5.5	1.7	7	15.0	10.4
3	6.5	1.8	7	17.5	11.2
3	7.5	1.9	7	20.0	12.1
4	7.5	3.0	8	17.5	14.6
4	8.5	3.2	8	20.5	15.2
4	9.5	3.4	8	25.5	17.1
4	10.5	3.6	9	21.0	18.9
5	9.75	4.8	9	25.0	20.4
5	12.25	5.5	9	35.0	24.8
5	14.75	6.1	10	25.0	24.4
6	12.25	7.3	10	35.0	29.3
6	14.75	8.0	12	35.0	38.0
6	17.25	8.7	12	50.0	50.6

* From "Pocket Handbook," Carnegie Steel Company, Pittsburgh Pa.

Questions and Problems

122. A signboard 24 ft. long and 12 ft. high is supported by four 6- by 6-in posts set into the ground. Considering these posts as cantilever beams, would they withstand a 60-mile wind at right angles to the board?

123. What size shortleaf yellow pine joists would be needed in a barn that is to be filled to a depth of 12 ft. with cut hay? The span for each joist is 12 ft., and spacing of joists is 2 ft. o.c.

124. A driveway through a crib is 10 ft. wide. Wheat is stored to a depth of 7 ft. over this driveway. What size, spacing, and material would you recommend for joists? Check for strength in bending and also for shear.

125. What kind and size of rafter would you use where rafters are 18′ 4½″ long? Figure roof load 30 lb. per sq. ft. perpendicular to the roof?

126. A barn 34 ft. wide has two girders extending through its length. They are placed 10 ft. apart on each side of a central feed alley. Loose hay will be stored to a depth of 15 ft. in the mow. Posts under the girder are spaced 10 ft. apart. The girder is made of shortleaf yellow pine built up as a continuous beam. What size would be required?

127. If 8-in. by 8-in. posts are used under the girder would the girder be safe from crushing? Shear?

128. What size steel I-beam could be used for this girder?

CHAPTER XXVIII

DESIGN OF COLUMNS AND FLOORS

Wood columns or posts have advantages over steel in that they can be worked by the ordinary carpenter, and in most localities wood in proper sizes is not difficult to secure. The material that is to be used for columns should be inspected carefully and discarded if defective, because the life of the structure depends upon the proper functioning of main supporting members such as the columns or posts. The size of stock needed for any column will depend on the length of the column, its shape, the material from which it is made, and the load to be carried.

172. Short Columns.—Columns in which the ratio of the length to the least diameter does not exceed 10 to 1 are called *short columns*. The safe load for short columns can be determined by multiplying the cross-sectional area by the strength of the material in compression with the grain. Or

$$SL = A \times C \tag{38}$$

where SL = total safe load for the column in pounds.
A = cross-sectional area in square inches.
C = strength in pounds per square inch in compression with grain.

In testing wood blocks for strength in compression, no differences in the tests will be noted until the ratio of the length of the column to the least diameter has exceeded 10 to 1. As the ratio exceeds 10 to 1, however, the safe load for the column decreases.

In a balloon frame the studs carry the load on the side walls. They are braced in the direction of their least diameter by the siding when horizontal siding is used; the safe load is determined by multiplying the total cross-sectional area of the studding by the strength in compression for the material. If vertical siding is used on a balloon frame, the studding will be braced by the nailing girts. If the full short-column loading is to be secured, it will be necessary to space girts at 20-in. intervals (10×2 in., the least diameter of the stud). However, if no girts or other cross members are used, the studs must be considered as long columns.

173. Long Columns.—Columns having a ratio of length to least diameter greater than 10 to 1 are called *long columns*. Most city building codes limit the ratio of length of column to least diameter to 30 to 1. For a long column the following formula is used

$$SL = \frac{(700 + 15M)AC}{700 + 15M + M^2} \tag{39}$$

where SL = safe load for the column in pounds.
M = the slenderness ratio; length in inches divided by least diameter.
A = cross-sectional area in square inches.
C = strength of the material to be used in compression with the grain in pounds per square inch.

Example: A post in a barn will be subjected to a load of 23,000 lb. The post is 7 ft. 6 in. high. Will a 5 by 5 oak post be strong enough? *Solution:* The slenderness ratio is 90/5 or 18; therefore it will be a long column. Substituting in the formula for long columns

$$SL = \frac{(700 + 15 \times 18)25 \times 1{,}300}{700 + 270 + 324}$$
$$= 24{,}362 \text{ lb}$$

Therefore the 5- by 5-in. post will be larger than necessary but should be used because the next smaller stock size ($4'' \times 4''$) would be too small.

TABLE 40.—SAFE LOAD FOR STEEL COLUMNS
Pipe not filled. $FS = 4$

Size*	Weight per foot	Outside diameter	Thickness of stock	Length of column excluding base and cap, feet							
				5	6	7	8	9	10	12	18
2″S	3.65	2.375	0.154	14,700	13,300	11,900					
2″E	5.02	2.375	0.218	19,900	17,900	16,000					
2½″S	5.79	2.875	0.203	25,000	23,200	21,300	19,500	17,800			
2½″E	7.66	2.875	0.276	32,800	30,300	27,800	25,200	23,000			
3″S	7.58	3.500	0.216	33,400	33,100	31,100	29,100	27,200	25,200		
3″E	10.25	3.500	0.300	45,200	44,400	41,700	38,900	36,200	33,600		
3½″S	9.11	4.000	0.226	40,200	40,200	39,600	37,500	35,400	33,300	29,300	
3½″E	12.51	4.000	0.318	55,200	55,200	53,900	51,000	48,000	45,100	39,700	
4″S	10.79	4.500	0.237	47,600	47,600	47,600	46,600	44,400	42,200	37,900	
4″E	14.98	4.500	0.337	66,100	66,100	66,100	64,300	61,200	58,100	52,000	
5″S	14.62	5.563	0.258	64,500	64,500	64,500	64,500	64,500	63,100	58,300	44,600
5″E	20.78	5.563	0.375	91,700	91,700	91,700	91,700	91,700	88,900	82,000	62,200

*S = standard pipe. E = extra strength.

Steel columns made in cylindrical form are well shaped to carry loads in compression. These columns must be fitted with bases and caps, however, to secure best results. Data on safe loads for steel columns of this type may be obtained from Table 40.

174. Reinforced Concrete Floors.—No attempt will be made to discuss the design of reinforced concrete in general, because it is beyond the limitations of this book. There is, however, need for information on design of reinforced floors on short spans, as in cribs and bins. Only one-way reinforcing will be considered. Such floors should be poured as a single unit, but the reinforcement will be planned as for beams 1 ft. wide.

It will be necessary to determine the load that will be applied to this 1-ft. strip of floor. (The weight of the concrete floor must be added, and therefore it will be necessary to estimate the thickness of floor that will be needed. If the estimate is too high or too low, additional estimates will be necessary.) Compute the bending moment produced by the load on this beam (1-ft. strip of floor). By substituting this bending moment in Table 41, the cross-sectional area of steel needed and the depth at which it should be placed in the concrete can be determined.

TABLE 41.—REINFORCEMENT FOR CONCRETE FLOORS

Slab			Area of steel reinforcement, square inches per foot width								
Thickness, inches	Depth of steel	Weight, pounds per square foot	0.10	0.20	0.30	0.40	0.50	0.60	0.70	0.80	0.90
			Bending moments, inch-pounds per foot of width								
2½	1¾	31.25	2,760								
3	2¼	37.50	3,672	7,092							
3½	2¾	43.75	4,524	8,760							
4	3¼	50.00	5,376	10,440	15,336						
4½	3¾	56.25	6,240	12,132	17,832	23,400					
5	4	62.50	6,672	12,972	19,080	25,056					
5½	4½	68.75	7,536	14,676	21,600	28,368					
6	5	75.00	8,400	16,380	24,120	31,704	39,144				
6½	5½	81.25	9,264	18,084	26,664	35,052	43,284				
7	6	87.50	10,140	19,800	29,196	38,400	47,448	56,364			
7½	6¼	93.75	10,572	20,664	30,468	40,080	49,536	58,848	66,012		
8	6¾	100.00		22,380	32,964	43,452	53,712	63,828	73,824		
8½	7¼	106.25		24,096	35,424	46,836	57,900	68,832	79,620		
9	7½	112.50		24,960	36,852	48,516	60,036	71,316	82,512	93,588	
9½	8	118.75		26,676	39,420	51,912	64,200	76,344	88,344	100,200	
10	8½	125.00		28,416	41,952	55,308	68,424	81,360	94,164	106,836	119,400

Example: A corn crib 7 ft. between foundation walls is 12 ft. deep. What thickness of reinforced floor should be used? What number and size of reinforcing rods would be needed? Each foot of length of floor would carry $7 \times 12 = 84$ cu. ft. of corn (Table 37 shows that corn weighs 28 lb. per cubic foot and concrete weighs 150 lb. per cubic foot); $84 \times 28 = 2{,}352$ lb., the weight of the corn. Assuming that the floor will be 6 in. thick, the weight of the floor will be $7 \times 0.5 \times 150 = 525$ lb., the weight of the concrete; $2{,}352 + 525 = 2{,}877$ lb. uniformly distributed load. This is a simple beam with a uniformly distributed load applied without impact, and the bending moment is therefore

$$\tfrac{1}{8} \times 2{,}877 \times 7 \times 12 = 30{,}208 \text{ in.-lb.}$$

From Table 41, we find that a BM of 31,704 in.-lb. with a floor depth of 6 in. would require 0.40 sq. in. of steel per foot of length of floor and that it should be placed 5 in. from the top of the slab. From the formula for Area $= \pi R^2$, we find that a $\frac{1}{2}$-in. round rod has an area of 0.2 sq. in. Therefore, $\frac{1}{2}$-in. rods spaced 6 in. apart or $\frac{3}{4}$-in. rods spaced 12 in. would meet the requirements.

Questions and Problems

129. A corn crib 8 ft. wide and 12 ft. deep is to have a reinforced concrete floor placed 3 ft. above ground. What thickness of concrete and what size and placing of reinforcement will be needed in this floor?

130. What load will a 6- by 6-in. oak post 56 in. long carry safely?

131. A post in a barn is subjected to a load of 34,600 lb. The post is 6 ft. 8 in. high. What size shortleaf yellow pine would be required? What size steel post would meet the need?

References

BETTS, M. C.: "Timber, Its Strength, Seasoning, and Grading," McGraw-Hill Book Company, Inc.

HOOL, G. A., and W. S. KINNE: "Stresses in Framed Structures," McGraw-Hill Book Company, Inc.

CHAPTER XXIX

GABLE ROOF FRAMING

In this chapter only regular roof types will be discussed, because any departure from the regular types becomes so involved and difficult as to be beyond the scope of this text. Framing regular roof types involves an intelligent use of the framing square.

175. The framing square is a tool that was designed to meet the needs of the carpenter at a time when the mortise and tenon type of framing was being used. The square carries a number of different measuring scales, each named according to its smallest division. For example, a $\frac{1}{8}$-in. scale is divided into $\frac{1}{8}$, $\frac{1}{4}$, $\frac{1}{2}$ in., etc., $\frac{1}{8}$ in. being the smallest division. Most of the special scales on the square are now obsolete, but it is sometimes convenient to know their use. The long part of the square is called the *body*, and the short projection, the *tongue*. The body is 24 in. long, and the tongue is 16 in. The square is made in these lengths for convenience in spacing studs and rafters (studs in barns are usually spaced 2 ft. on centers and in houses, 16 in. on centers). The *face* of the square is the side that carries the manufacturer's stamp. The outside scale on the face is usually divided into sixteenths of an inch, numbered from the heel of the square. The inside scale on the body is usually divided into eighths of an inch. The outside scale on the back of the square is divided into twelfths and is the one used in laying off rafters and in determining their lengths. The inside scale on the back of the body is usually in thirty-seconds of an inch and on the tongue, in tenths.

On the back side of the body is a series of numbers under each of the inch marks on the outside scale. This is the *board measure scale*. To use it, start at 12 on the outside scale, and move down until a number corresponding to the width of the board is found. Move right or left on this line to a number on the outside scale

representing the length of the board in feet. Read the number there, and it will be the board feet and twelfths of board feet in the piece if the piece is 1 in. thick. Double this number to find board feet for 2-in. lumber, etc.

On the back side of the tongue is the *brace scale*. This is used to determine the length of brace needed when braces are placed at 45-deg. angles with the posts and beams. If a brace is to be spaced 30 in. out from the junction of two members, the numbers "30 over 30" indicate the spacing, and 42.43 in. (the number

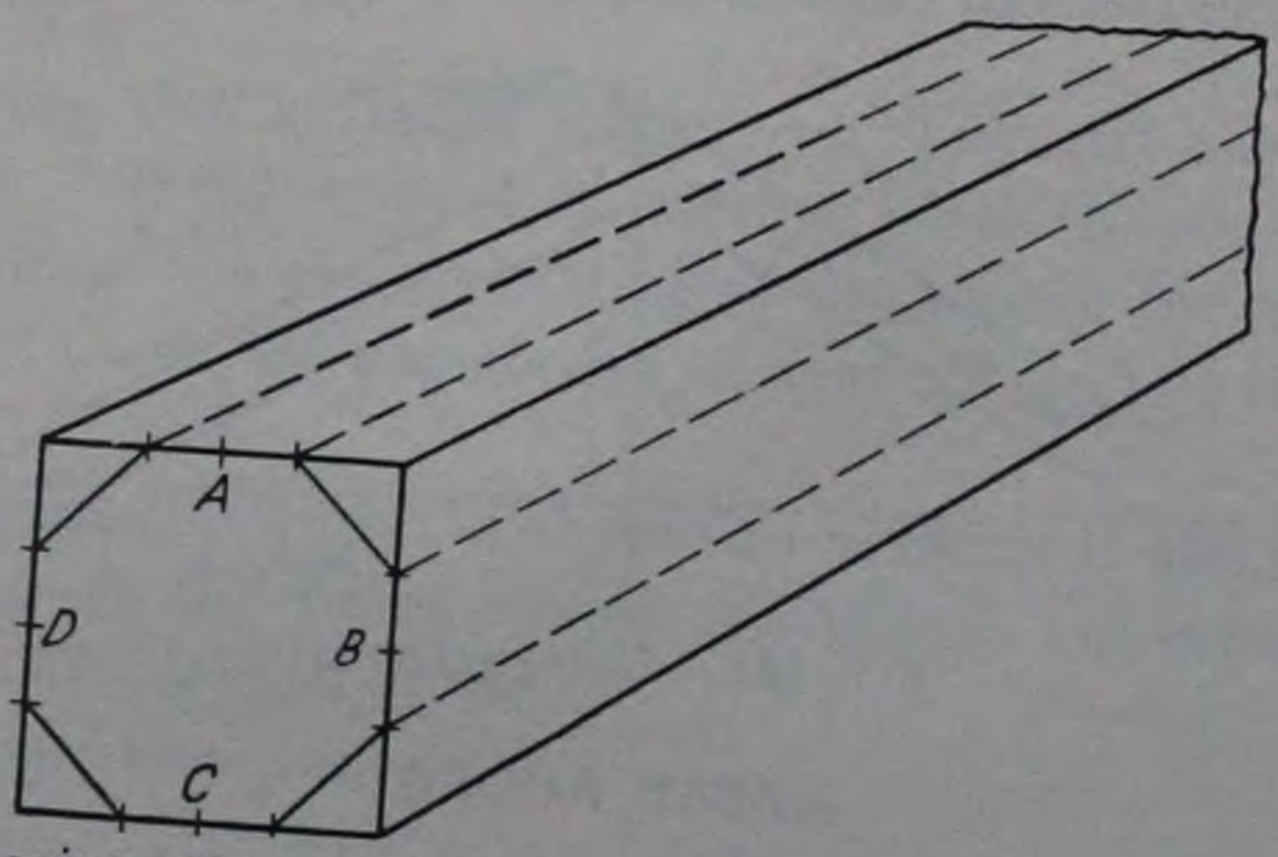


FIG. 120.—Laying out an octagon post with the octagon scale. Looking at the end of the post, locate the center points on each edge as at *a*, *b*, *c*, and *d*. Take a pair of dividers and set one point on zero on the octagon scale, and the other on a number representing the thickness of the stock used. If the post is 10 by 10 in. square, then set the dividers on 0 and 10 on the octagon scale. Using points *a*, *b*, *c*, and *d* as centers, locate points on each side of these center points by use of the dividers.

placed at the right) is the length of the brace required ($^{30}/_{30}$ 42.43 in).

The *mortise scale* on the face of the body is numbered in inches from the point of the body and is used in measuring the depth of mortises. The *octagon scale* on the face of the tongue is used in making eight-sided porch posts or columns from square stock (see Fig. 120 for method of laying out an octagon post). The scale consists of a number of dots on the square numbered from 0 to 65.

176. Terms in Use in Roof Framing.—In roof framing certain terms are used in common practice that must be understood before studying the subject. The term *pitch* is used in describing the slope of a roof and is defined as follows: Pitch is equal to the

rise divided by two times the run, where the *rise* is the vertical distance between the ridge and the plate and the *run* is the horizontal distance covered by the rafter (see Fig. 121). The *plumb cut* is the vertical cut at the upper end of the rafter. The *bird's-mouth* is the 90-deg. notch in the rafter that fits on the plate. The *fascia cut* is the vertical cut on the outer end of the rafter. The *plancher cut* is the horizontal cut on the outer end of the rafter. The fascia cut and plancher cut meet on the *work line*, which is a straight line drawn parallel to the edges, usually 2 in. from the bottom edge of the rafter (see Fig. 122).

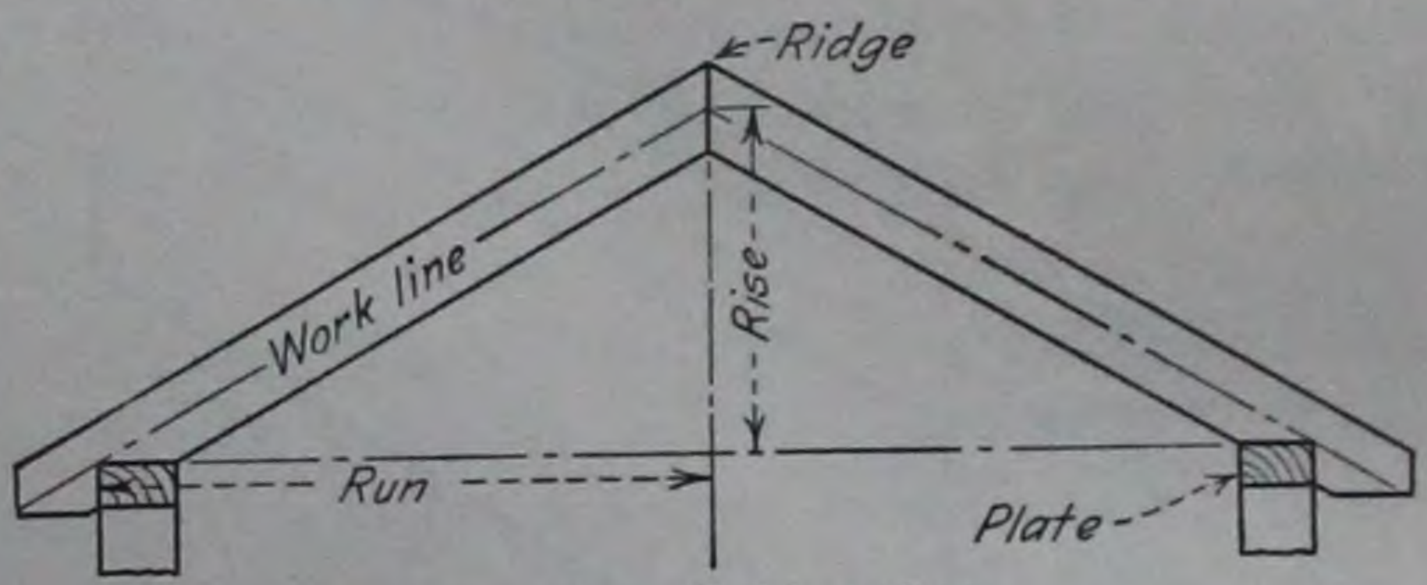


FIG. 121.—Gable rafters.

GABLE ROOFS

In a gable roof both slopes have the same pitch, and the rafters, of course, are alike. The ridge is directly over the center of the building.

177. Setting the Square for the Pitch.—There are many methods for laying out a gable rafter. The method selected here is used because it can be followed through in framing the different kinds of roofs discussed later. In this method all the cuts are secured by setting the square on the stock so that the 12-in. mark on the body of the square and the figure on the tongue representing the rise in inches per foot of run for the pitch specified coincide with the work line. For steep pitches it may be necessary to let the tongue represent the run and the body, the rise. In either case, the horizontal line should be secured by marking along the side of the square representing the run and the vertical line secured by marking along the side representing the

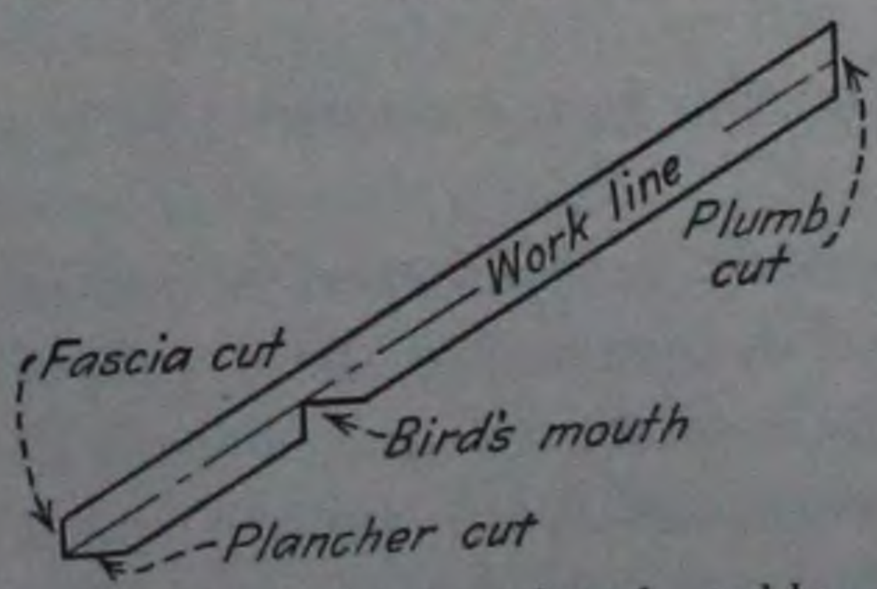


FIG. 122.—A completed gable rafter.

rise. Before this step can be carried out it will be necessary to determine the rise per foot of run. This may be determined by the formula

$$\text{Pitch} = \frac{\text{rise}}{2 \times \text{run}} \tag{40}$$

Assuming a $\frac{1}{8}$ pitch, we have $\frac{1}{8} = \frac{\text{rise}}{2 \times 12}$, or $8 \times \text{rise} = 2 \times 12$, or rise = 3 in. for each foot of run. A short cut to determine the rise per foot of run is to multiply the pitch by 24. For example, $\frac{1}{8} \times 24 = 3$ in.

178. Laying Out a Gable Rafter.—*a.* Lay out the work line on the stock. If rafter stock is warped, place the crown side up.

b. Determine the proper setting of the square for the pitch to be used, and mark the plumb cut as near the end of the stock as possible.

c. Determine the length of the rafter, and lay it off on the work line, starting at the point where the plumb cut intersects the work line. The length of the rafter may be determined by any one of the three methods described in Art. 179. Use two methods as a check.

d. After the length has been determined and marked on the work line, the next step is to lay off the bird's-mouth. Set the square for the pitch, and lay off the horizontal cut for the bird's-mouth. Slide the square down the stock, and mark the vertical cut of the bird's-mouth.

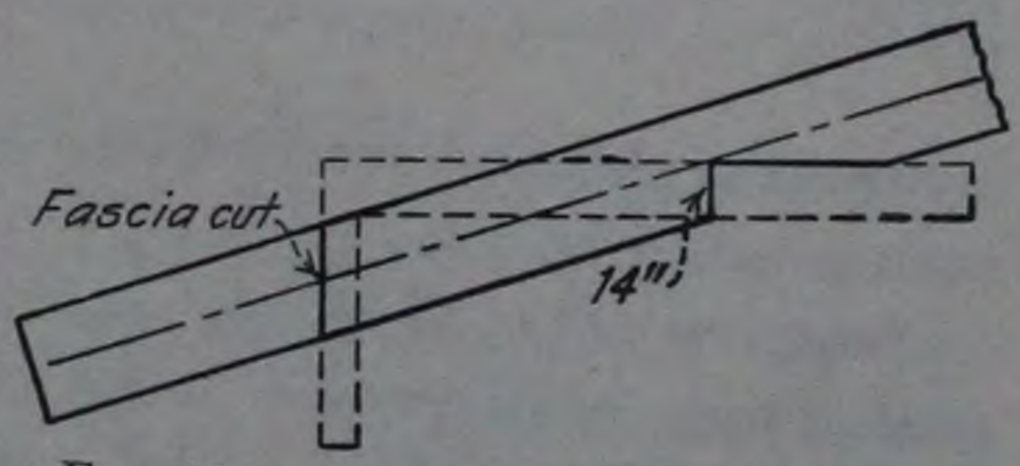


FIG. 123.—Laying off the fascia cut.

e. Lay off the projection. Projection refers to the *horizontal* distance that the roof water will be carried from the building or the horizontal distance covered by the overhang of the roof. If the projection is to be 14 in., place the square with the 14-in. mark at the corner of the bird's-mouth, hold the body of the square parallel to the horizontal mark for the bird's-mouth, and mark on the tongue of the square for the fascia cut (see Fig. 123).

f. Lay off the plancher cut. The plancher cut is made in the same manner as the horizontal cut of the bird's-mouth.

179. Determining Rafter Length.—*The Square-root Method.*—To use this method, the total run and rise of the rafter must be

determined. Using these two figures as the sides of a right triangle, compute the hypotenuse. The hypotenuse of this triangle will be the length of the rafter, measured on the work line, required to extend from the outside edge of the plate to the ridge.

Measuring on the Square.—The outside scale on the back of the framing square is divided into twelfths of an inch. On this scale let 1 in. = 1 ft. and $\frac{1}{12}$ in. = 1 in. After finding the total rise and total run, lay off to this one-twelfth scale the feet and inches of rise on the tongue of the square and the feet and inches of run on the body. Measure the hypotenuse of this triangle with the

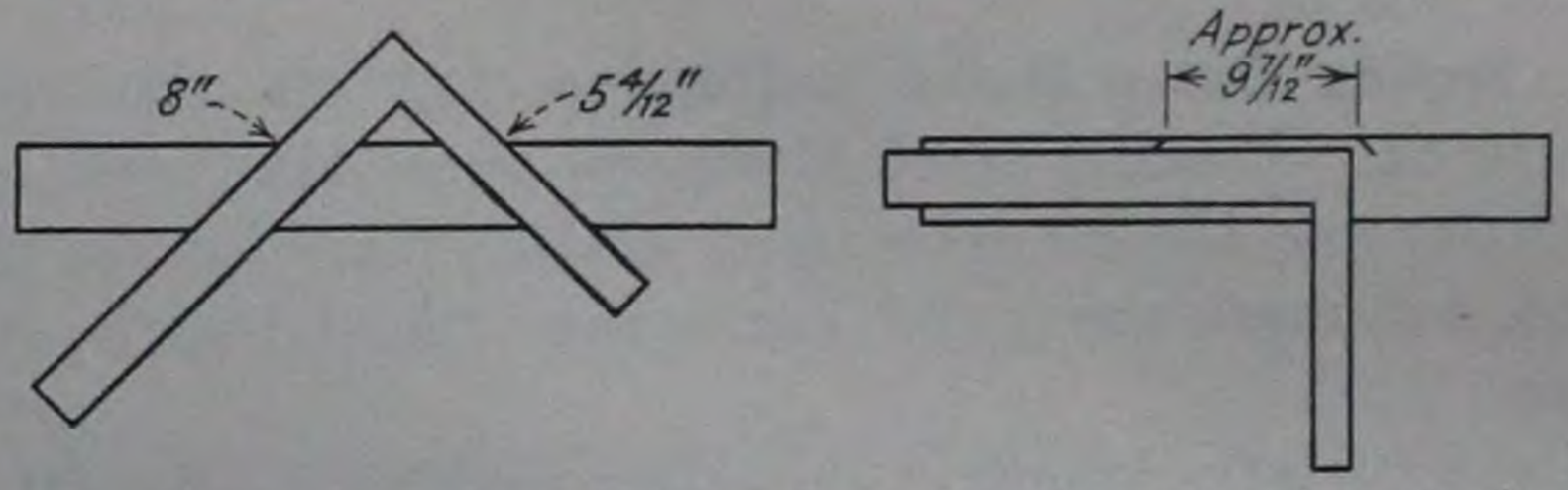


FIG. 124.—Determining the length of a rafter by measuring on the square. In the illustration the length of a rafter for a building 16 ft. wide with a $\frac{1}{3}$ pitch roof is determined. The total run of each rafter is 8 ft. and the total rise is 5 ft. 4 in. The measured distance is $9\frac{7}{12}$ in. approximately, or 9 ft. 7 in.

reduced scale, and read off the length of the rafter in feet and inches (see Fig. 124).

Stepping Off.—With the square set for marking the vertical plumb cut, as described in Art. 177, make a mark on the work line coinciding with the 12-in. mark on the body of the square. This completes the first step. For the succeeding steps, move the square so that the figure on the tongue representing the rise per foot of run coincides with the mark made on the work line in the preceding step and the 12-in. mark on the body coincides with the work line. Take as many of these steps or fractional steps as there are feet or fractional feet of run to be covered by the rafter (see Fig. 125).

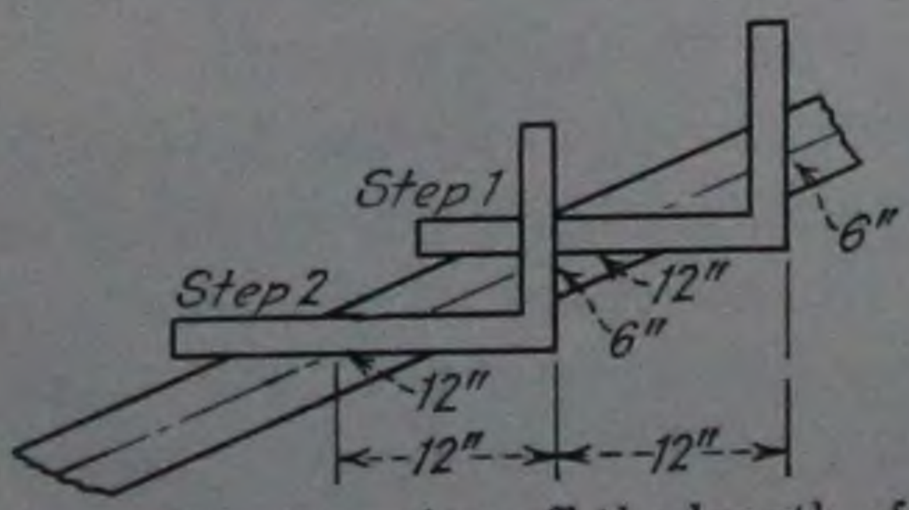


FIG. 125.—Stepping off the length of a rafter.

180. Combination Rafters.—The process of laying out combination rafters is the same as for gable rafters except that the run and pitch of the two rafters making up the pair are not the same. In most cases the long rafters cover two-thirds the width

of the building and the short rafters one-third the width. This is known as a *two-thirds span* and is the division ordinarily used; the relation, however, may be three-fourths and one-fourth or any other division desired. The rise of each rafter in a pair is the same because they each extend from the plate to the ridge, but since the run is not the same the pitch of the rafters will be different. If the width of the building and the setting of the square for the different pitches are known, the length of the rafters may be determined.

If a combination roof is specified and nothing is mentioned about the span of each rafter, it is generally understood that a two-thirds span is to be used (see Fig. 126).

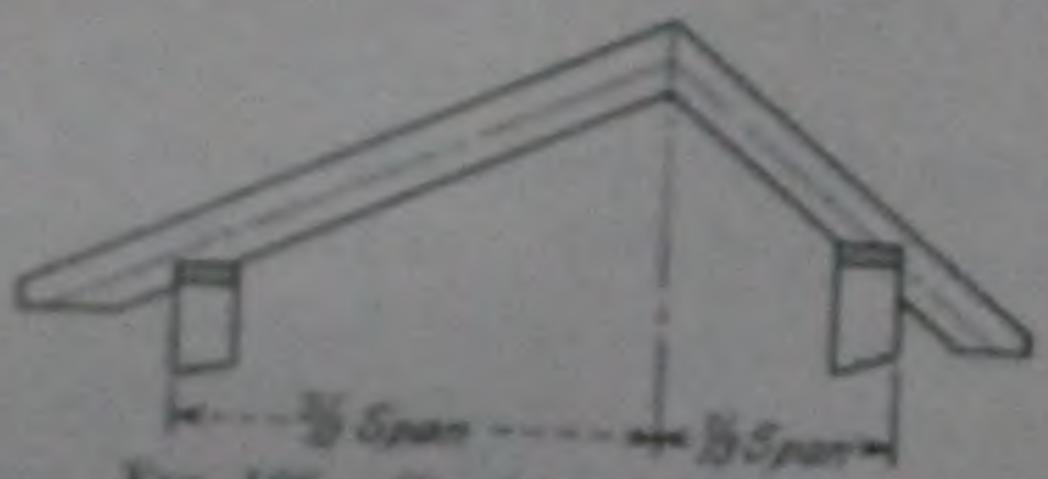


FIG. 126.—Combination rafters.

181. Shed Rafters.—In a shed roof the two plates are placed at different heights to give pitch to the roof. The bird's-mouth and fascia cuts for the lower end of the shed rafter are made in the same manner as for the gable rafter. Two bird's-mouths, cut alike, are used, one to fit on each plate (see Fig. 127).

In computing the run, figure the horizontal distance from the outside of the lower plate to the inside of the studding under the upper plate, because the computations and measurements are taken from the points of the upper and lower bird's-mouths. To compute the length of the shed rafter we must know the width of the building, the width of the upper plate and studding, and the difference in the height of the lower and upper plates. In laying off the projection on the upper side, the width of the plate must be added to the horizontal projection if it is measured from the point of the bird's-mouth. Fascia cuts are ordinarily used to complete the rafter.

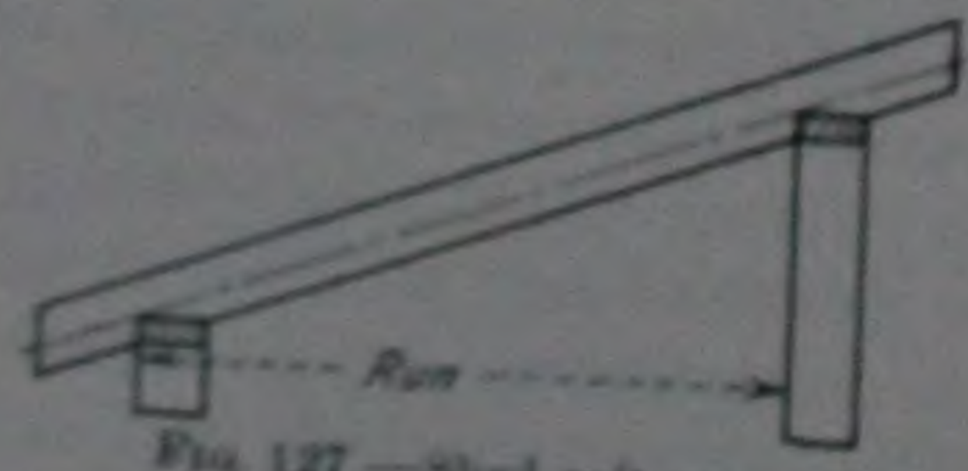


FIG. 127.—Shed rafters.

Questions and Problems

132. Compare the different types of barn roofs as to ease of construction, appearance, cost, efficiency in use of materials, and advantages to the building covered.

133. Make a sketch of a gable rafter for a building 26 ft. wide. The roof is to have a ¼ pitch and an 8-in. projection. Show all length dimensions and the setting of the square for cuts. Use a scale ¼ in. = 1 ft.

134. Make a sketch showing a pair of combination rafters for this building, the long rafter to have ⅛ pitch.

CHAPTER XXX

GAMBREL, GOTHIC RAFTERS

Gambrel and Gothic types of roofs are used extensively on barns because of the advantage of securing a large amount of storage space in the mow. However, this type of roof creates a problem where an attempt is made to use one type of architecture throughout the farmstead. Other buildings are not well adapted to this type of roof, and consequently there is a lack of unity in the architecture of the farmstead group.

182. Design of Gambrel Rafters.—Each side of the gambrel roof is made up of two slopes. This type of roof truss approximates an inverted catenary curve and gives the best placement of materials for arch construction. Therefore, if the joints in a gambrel roof are designed to fall on or near this curve, the best placement of materials in the roof truss will probably result. (A catenary curve is approximately the curve assumed by a chain suspended freely by its ends. The length of chain in this case is equal to a semicircle in which the diameter is the same as the width of the barn and the distance between the points of suspension, equal to the width of the barn.) The first rafter is cut to set at approximately 60 deg. and the second rafter at approximately 30 deg. with the horizontal. The lower rafter then has a $\frac{6}{7}$ pitch and the upper one a $\frac{7}{24}$ pitch (see Fig. 128). Full pitch and $\frac{1}{4}$ pitch have been used, but the rafters are not then so well placed to meet the strains as in the first-mentioned placing.

In this type of roof, since the outside edge of the lower rafter is placed even with the outside edge of the plate, the work line is the outside edge of the rafter. To lay off the horizontal cut on the lower rafter, the square is placed on the stock with the 7-in. mark on the tongue and the 12-in. mark on the body coinciding with the work line. This same setting is correct for the plumb cut on the upper rafter. The cut at the junction of the two pitches is laid off by placing the square on the stock with the $3\frac{5}{32}$-in. mark on the tongue and the 12-in. mark on the body coinciding with the work line. This makes the upper and lower

TABLE 42.—DATA ON GAMBREL RAFTERS*

Width of barn	Length of lower rafter, feet	Length of upper rafter
18	8	5 ft. 9 in.
20	9	6 ft. 2⅜ in.
22	10	6 ft. 7¾ in.
24	12	6 ft. 10¾ in.
26	12	8 ft. ½ in.
28	14	8 ft. ½ in.
30	14	9 ft. 2⅜ in.
32	14	10 ft. 4¼ in.
34	16	9 ft. 6⅛ in.
36	16	11 ft. 6 in.
38	18	11 ft. 6 in.
40	18	12 ft. 7⅞ in.

* Data apply to $\frac{6}{7}$ and $\frac{7}{24}$ pitches.

rafters exactly alike except for length. Table 42 gives the length of each rafter for different barn widths.

183. Wing-joist or Braced-rafter Framing.—The gambrel-roof truss may be constructed in several ways. The wing-joist or braced-rafter type is shown in Fig. 129. This is one of the most popular types and is recommended for barns 34 ft. wide and less.

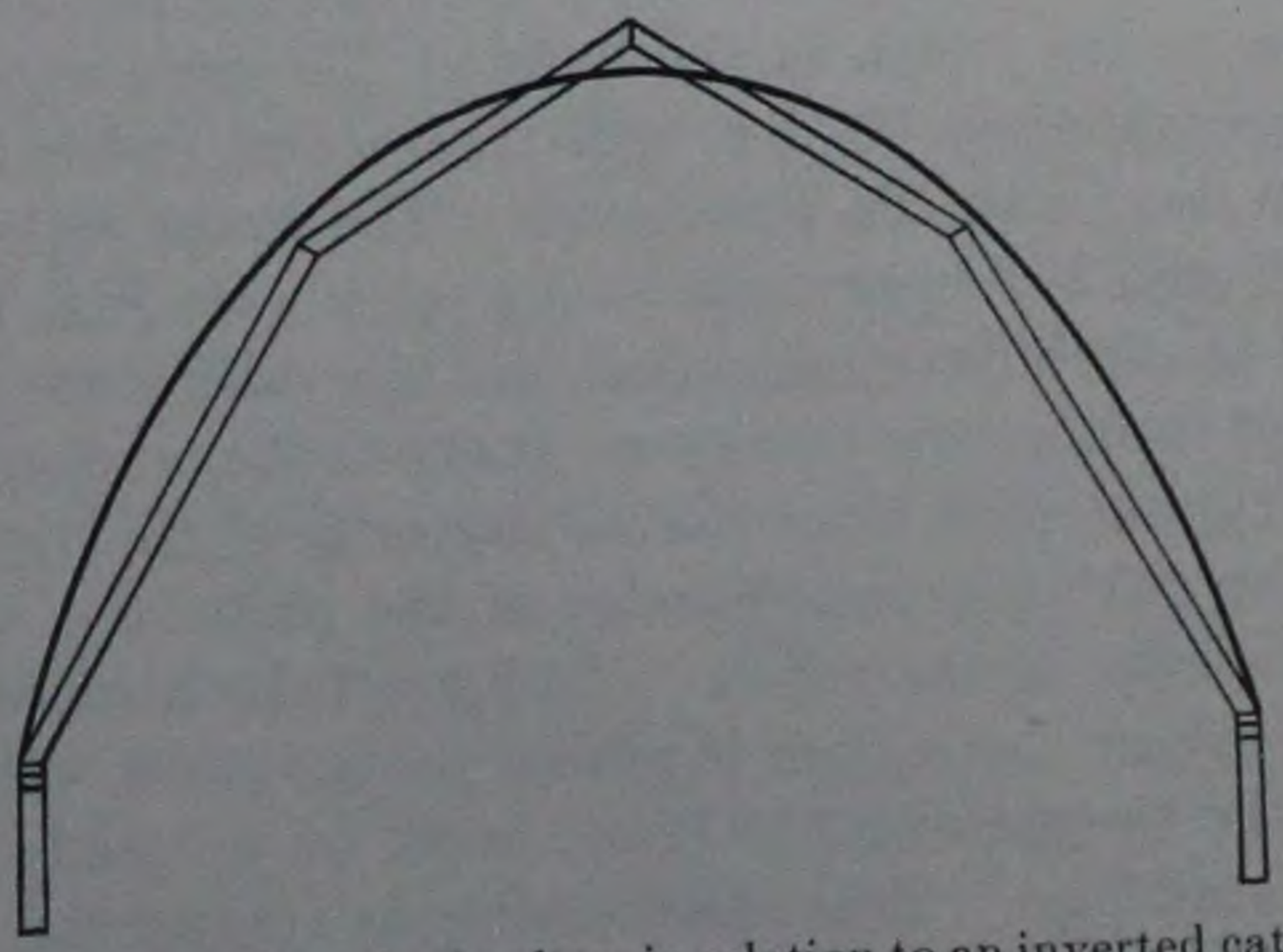


FIG. 128.—Position of gambrel rafters in relation to an inverted catenary curve. In this roof pitches of $\frac{6}{7}$ and $\frac{7}{24}$ are used. This shows the first joint in the roof slightly inside the curve and the joint at the ridge a little above the curve. When full and $\frac{1}{4}$ pitch rafters are used the first joint falls on the curve, but the joint at the ridge falls appreciably below the curve, which reduces its effectiveness as an arch.

In this type of construction each pair of rafters forms a truss. Each angle between rafters and studding is braced across to give stiffness to the completed truss.

184. The Iowa Truss.—In the Iowa type, a truss is built up at each bent (usually every 12 ft.). The ridge, the purlin (the supporting member for the roof between the plate and the ridge), and the plate are designed to carry the rafters between trusses.

FIG. 129.—Wing-joist or braced-rafter type of roof.

The posts supporting the truss are tied in from the plate to the joists to prevent spreading. A box plate is used to secure the stiffness necessary to carry the roof load between posts. Vertical siding helps to support the plate and is ordinarily used with this type of roof (see Fig. 130).

185. The Shawver truss was used formerly in gambrel-roof construction but is seldom used at present (see Fig. 131). It requires a compression member to support the purlin. This

member must be made heavy enough to prevent buckling and must be made from extra-length material. This extra-length material is not ordinarily stocked in the lumberyard, and, as a result, this type of roof truss is very expensive.

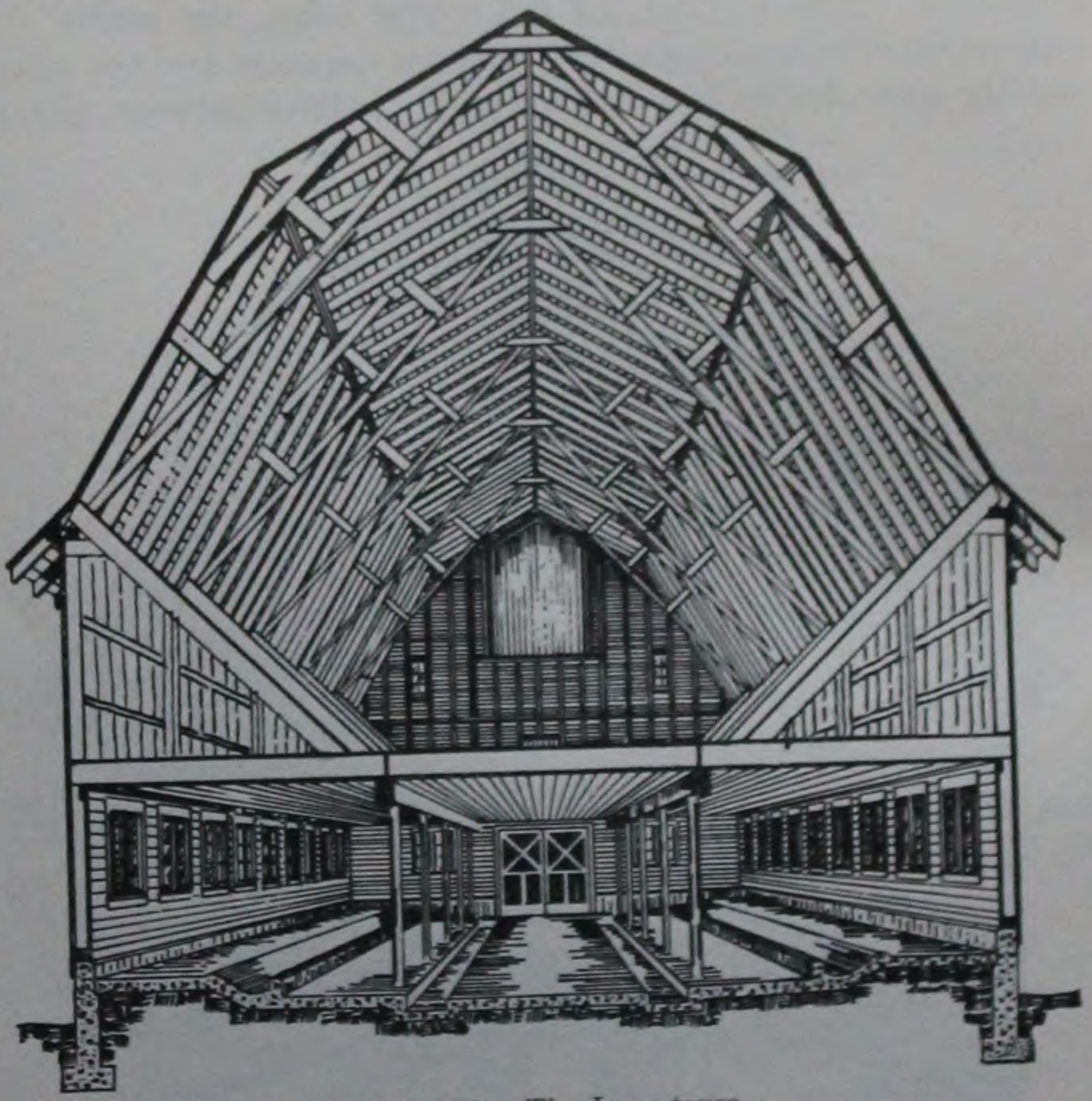


FIG. 130.—The Iowa truss.

THE GOTHIC ROOF

186. Design of Gothic Rafters.—Gothic rafters are made by bending or sawing the stock into the form of an arc of a circle, the radius of which is equal to two-thirds the width of the building. The center for the arc is located on the plate line that is lowered so as to make the height at the ridge approximately the same for the gambrel roof. These rafters are made sufficiently strong to hold their shape without bracing, thereby giving a maximum storage space in the mow.

187. Sawed Rafters.—Sawed Gothic rafters are made by nailing wide boards together so that the outside edges will trim to the

desired radius with a minimum of loss and with the best placing of materials for strength. The rafter may be cut to shape with an ax or a saw. From four to six one-by-twelves in varying lengths are used for this type of rafter, depending on the span and the strength needed.

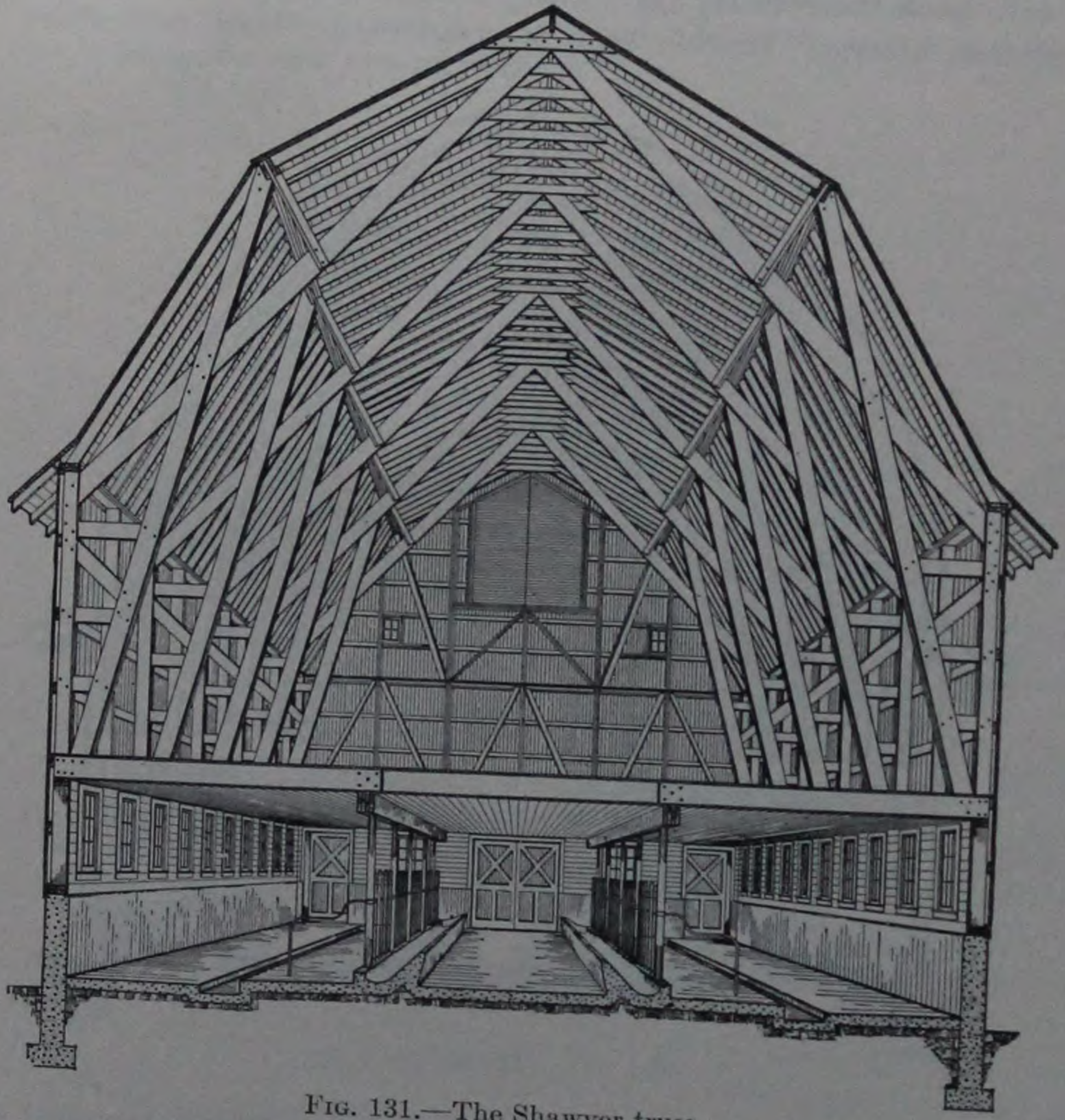


FIG. 131.—The Shawver truss.

188. Bent rafters are constructed by bending from three to six one-by-fours or one-by-sixes to the curve desired, then bolting, nailing, or gluing them so that they will hold their shape. A combination of sawed and bent rafters or trusses is used extensively where a Gothic roof is desired. The sawed rafters are used at each bent (every 12 ft.), and the fillers in between are of the bent-rafter type (see Fig. 132).

189. Combination frame and roof trusses can be made, using built-up standing and rafters all in one piece. This type of construction offers some difficulty in fastening the joists, and also requires the use of horizontal siding.

190. The semicircular frame and roof truss is used in some sections of the country for poultry houses, barns, or machinery-storage houses. In this type of construction bent rafters are

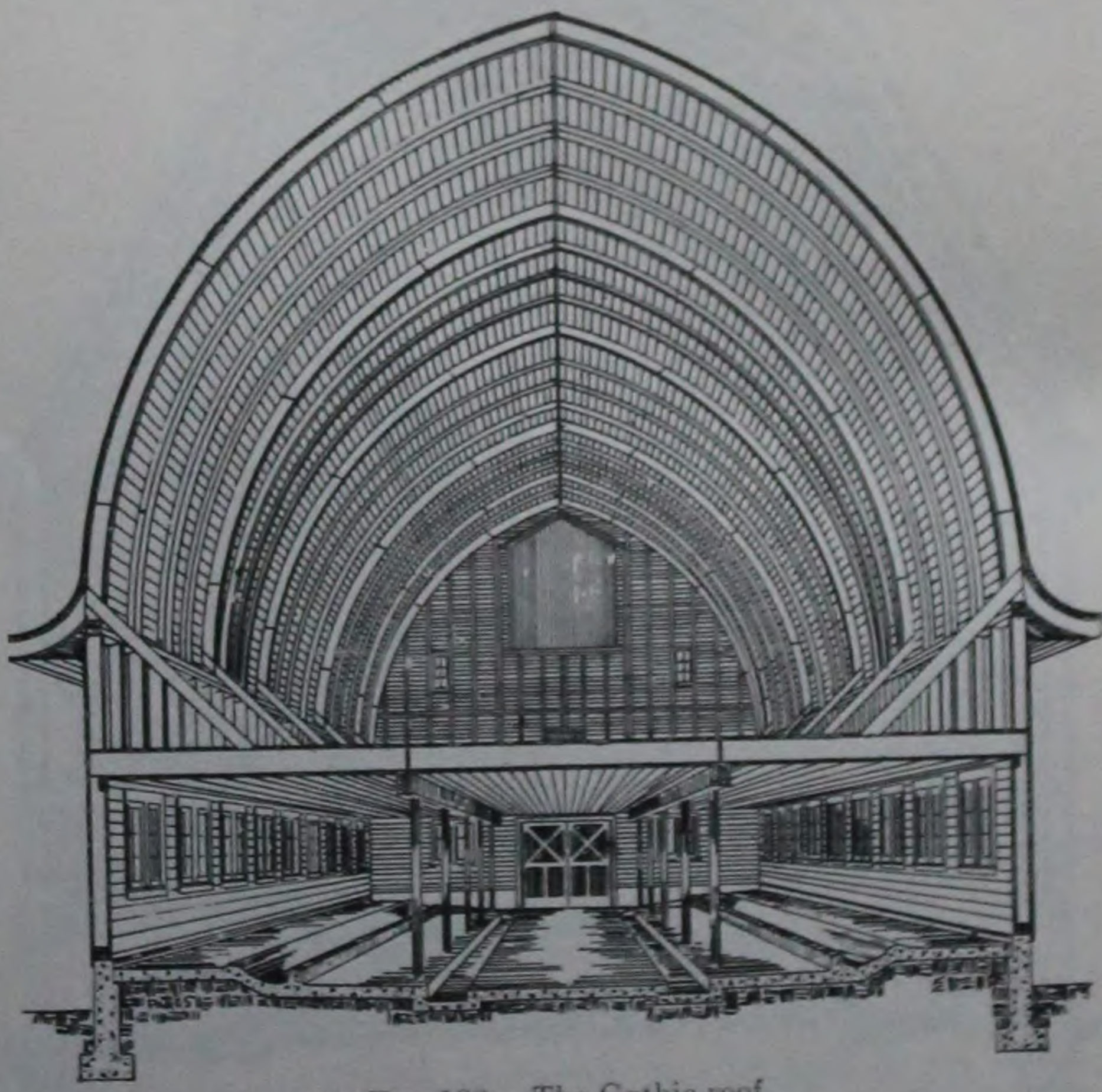


FIG. 132.—The Gothic roof.

built up in the form of a semicircle and are securely fastened to the sill and the foundation. They are spaced from 2 to 3 ft. apart and then sheathed solid. To add strength, secure better roof drainage, and improve the appearance of the structure, a ridge board is placed above the rafters, and construction is built out from it. This semicircular type has some advantages over the conventional type of structure. It requires ordinary stock lumber throughout; it is economical of materials and has no

opening at the junction of roof and walls through which heat would be lost.

Questions and Problems

135. Using a scale of 5 ft. equals 1 in., draw a sectional view of a barn 34 ft. wide; 12 ft. to the plate, 2 by 6 studding, and a 4- by 6-in. plate; mow floor 9 ft. above ground floor. Show a pair of wing joist rafters in place.

136. Show the same barn with a gothic roof. Lower the plate to give the two buildings the same over-all height.

CHAPTER XXXI

THE HIP ROOF[1]

The hip roof is constructed so that water falling on the building drains off on all four sides (see Fig. 133). The rafter that crosses the corner of the building and carries the sheathing for the two adjacent slopes is called the *hip rafter* (see Fig. 134). If the building is square the four hip rafters meet at the center. In all

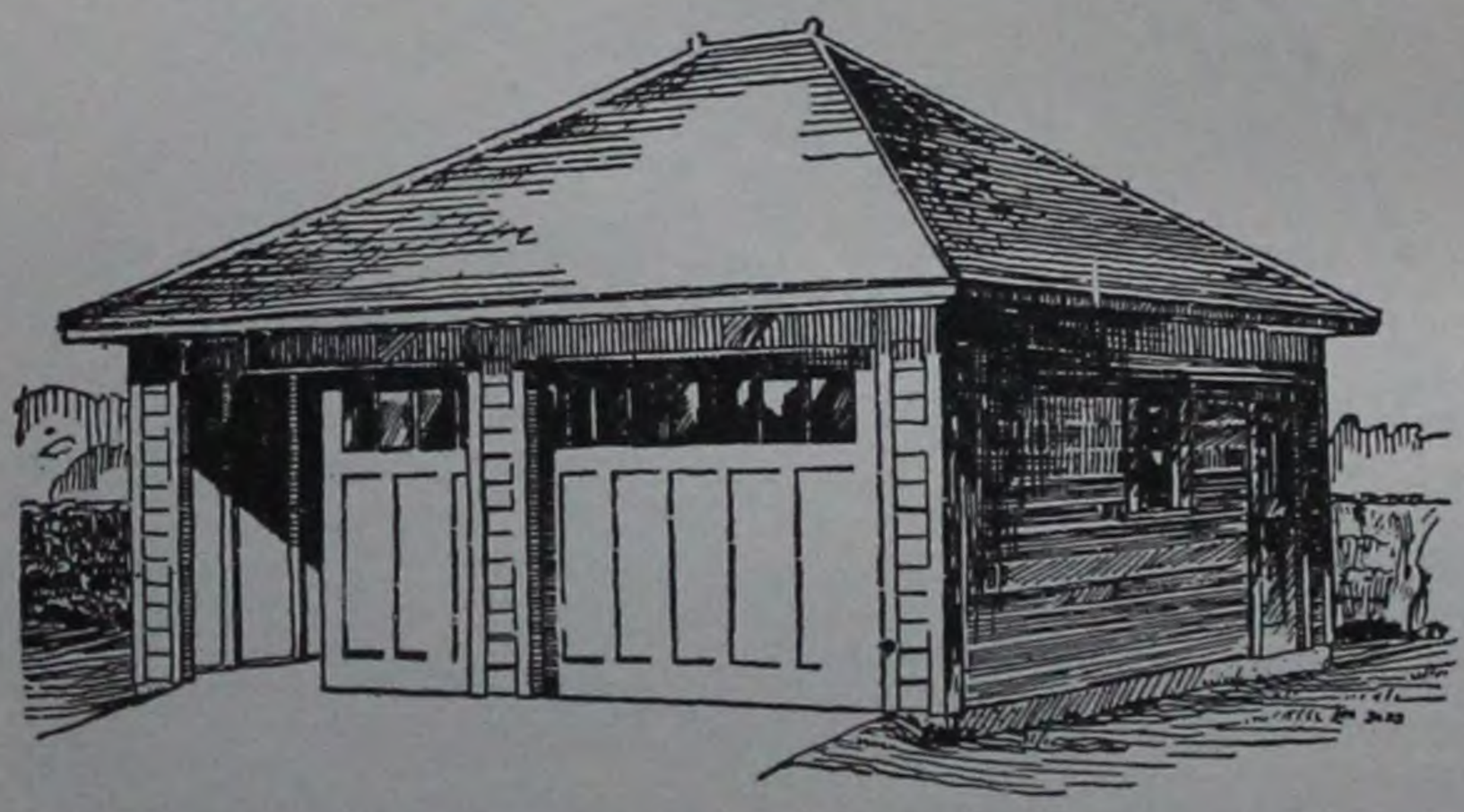


FIG. 133.—A hip roof.

regular hip-roof construction the hip rafters cross the plate at 45 deg.; or, in other words, this rafter bisects the 90-deg. angle made by the two sides of the building.

191. Laying Out a Hip Rafter.—The run, or the horizontal distance covered by the rafter, is the diagonal of a square formed by the run of the gable rafter, or a distance equal to one-half the width of the building. The rise of the hip rafter is equal to the rise of the gable rafter for the pitch of roof specified. In cutting gable rafters, a setting on the framing square of 8 and 12 in. for the plumb cut for a $\frac{1}{3}$ pitch roof was used. For the hip rafter use a rise of 8 in., and a run equal to the diagonal of a square 12 in. on each side, or approximately 17 in. Then, in

[1] This discussion has to do only with hip roofs that have equal pitches on all sections of the roof.

making the side mark of the plumb cut, use a setting of 8 and 17 in. and, for horizontal cuts, 17 and 8 in.

To lay off the plumb cut for the hip rafter, set the square so that the 8- and 17-in. marks coincide with the work line, and mark along the 8-in. side. Then square across the top and down

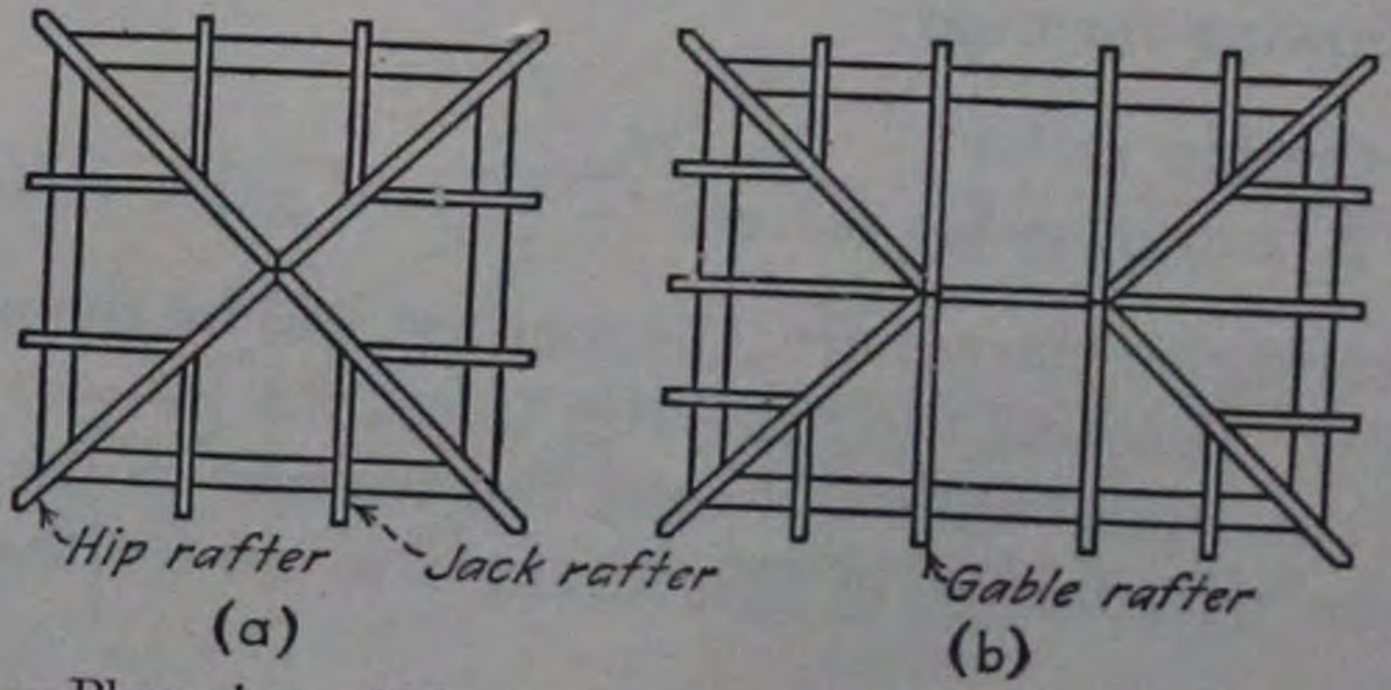


FIG. 134.—Plan view of hip roof: (*a*) square roof; (*b*) rectangular roof.

the other side by setting the square on 8 and 17 in. again, as shown in Fig. 135 by lines AA and $A'A'$.

The plumb cut must be pointed so that the four hip rafters will fit against each other if the building is square or against the gable rafters if the length of the building is greater than the width. To secure this cut, move the square toward the end of the stock

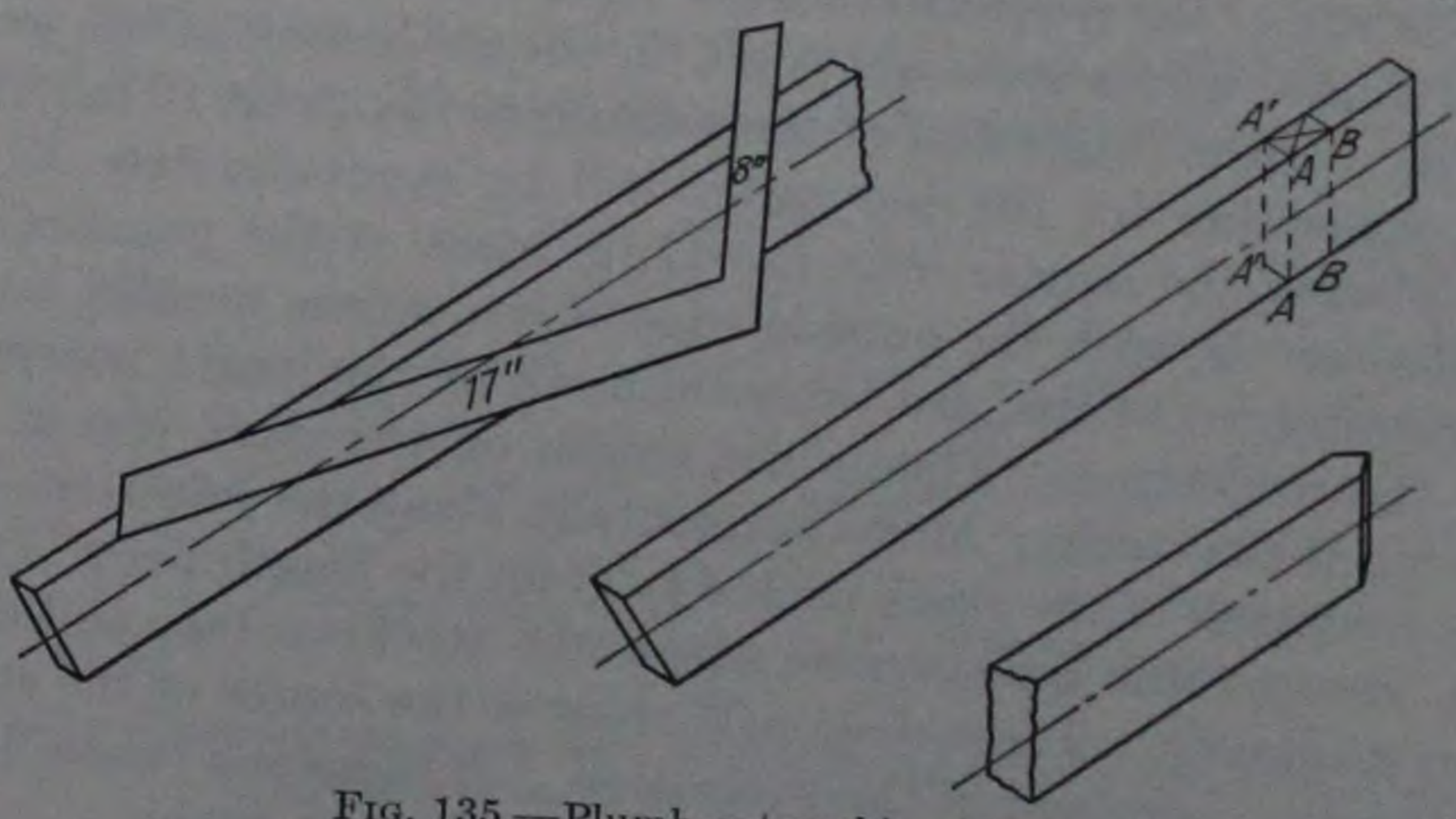


FIG. 135.—Plumb cut on hip rafter.

at right angles to the mark previously made for the plumb cut (AA, Fig. 135) a distance equal to the thickness of the stock used. Draw line BB parallel to AA, square across the top, and draw diagonals as shown. The length of the rafter should be measured from the point of the rafter at the work line that is half the dis-

tance between lines AA and BB. This length can be computed in any of the three ways used for gable rafters.

If the square-root method is used, it is necessary to find the total run and the total rise of the rafter, square them, and find the square root of their sum. To shorten the process we may use the following formula:

$$\text{Length of the hip rafter} = \sqrt{2\ (\text{run of gable rafter})^2 + (\text{rise of gable rafter})^2} \quad (41)$$

In measuring on the square, the method will be the same as for gable rafters. Lay off the total rise to scale 1 in. = 1 ft. on the tongue of the square and the total run to scale on the body, and measure the hypotenuse of this triangle to secure the length of the rafter.

If the length is to be secured by stepping it off, take as many steps as would be necessary in stepping off a gable rafter for the same building, with the exception that 17 in. should be used instead of 12 in. on the body of the square.

After the length has been determined, the bird's-mouth is laid off in the same manner as for gable rafters except that in setting the square for the pitch a run of 17 in. is used instead of 12 in.

The run of the projection for the hip rafter will be the diagonal of a square whose sides are equal to the projection of the gable rafter. If the projection of the gable rafter is to be 12 in., then the projection for the hip rafter will be approximately 17 in. By placing the square with the 17-in. mark at the point of the bird's-mouth, with the outside edge of the square parallel to the horizontal cut of the bird's-mouth, mark off the length necessary for the projection. This is the length on the work line at the center of the stock. Move horizontally along the rafter one-half the thickness of the stock each way from the length line. Draw the vertical side lines square across the stock on top, and draw two diagonals. These diagonals cross at the center of the stock, giving the outer end of the projection. If there is a fascia board on each side, the pointed rafter will fit into each plane.

This completes the rafter with one exception. The hip rafter would be the proper height at the center on the top surface, but the edges would be too high, and the sheathing would be bent up from the plane of the gable rafters. Two methods can be used to bring the hip rafter down into the same plane as the gable rafter.

One method is to lower the edges of the rafter by cutting the bird's-mouth deeper, and the other method is to crown the rafter, cutting off the projecting edges (Figs. 136 and 137).

192. Jack Rafters.—The variable-length rafters extending from the plate to the hip rafter are called *jack rafters*. The

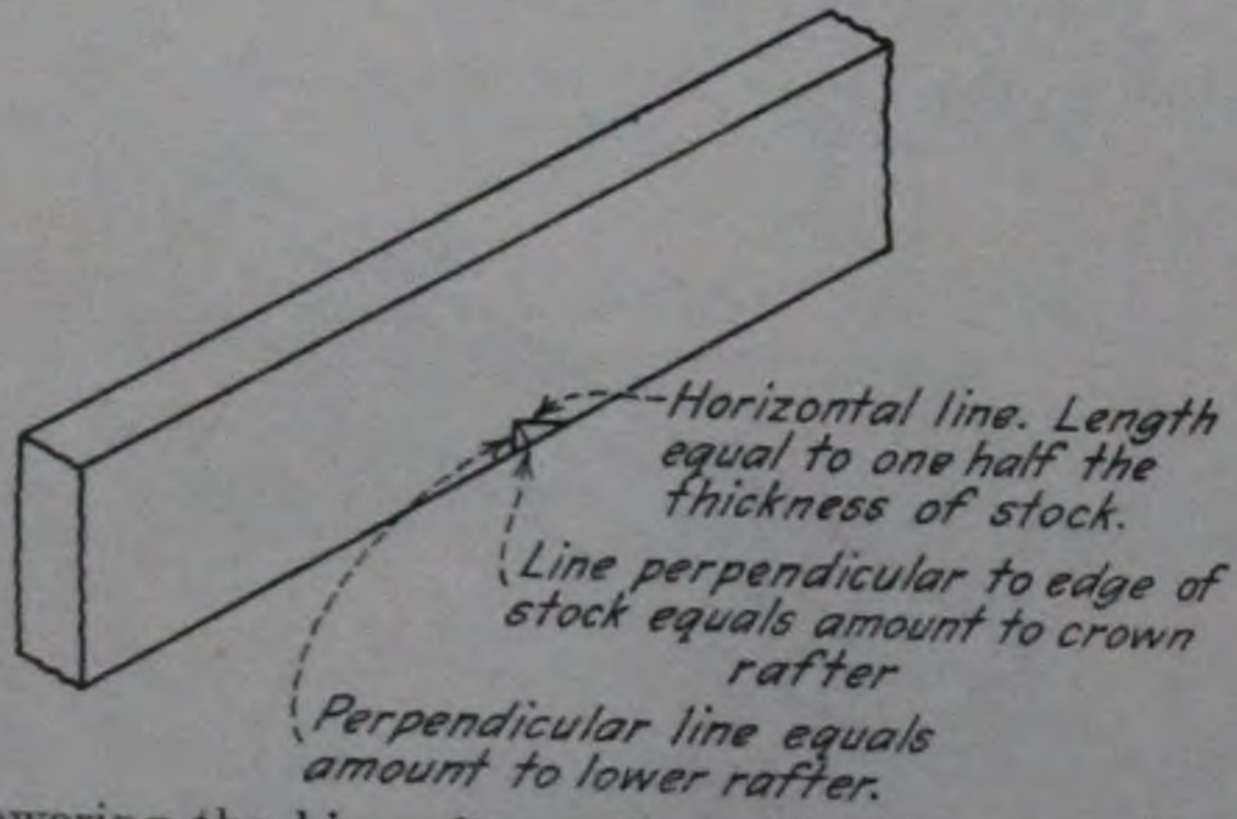


FIG. 136.—Lowering the hip rafter. To determine the amount to lower the rafter, proceed as follows: With rafter set in place, draw a horizontal line on it. From the lower edge of the rafter, measure in on this line a distance equal to half the thickness of stock being used. From this point produce a vertical line to the edge of the stock. The length of this line is the amount to lower the rafter in the bird's-mouth.

bird's-mouth, fascia, and plancher cuts are the same as for gable rafters. To find the length of the jack rafter, it is necessary to know the run and the pitch of the roof. Jack rafters are usually placed 2 ft. apart, the same distance as for gable rafters. The run

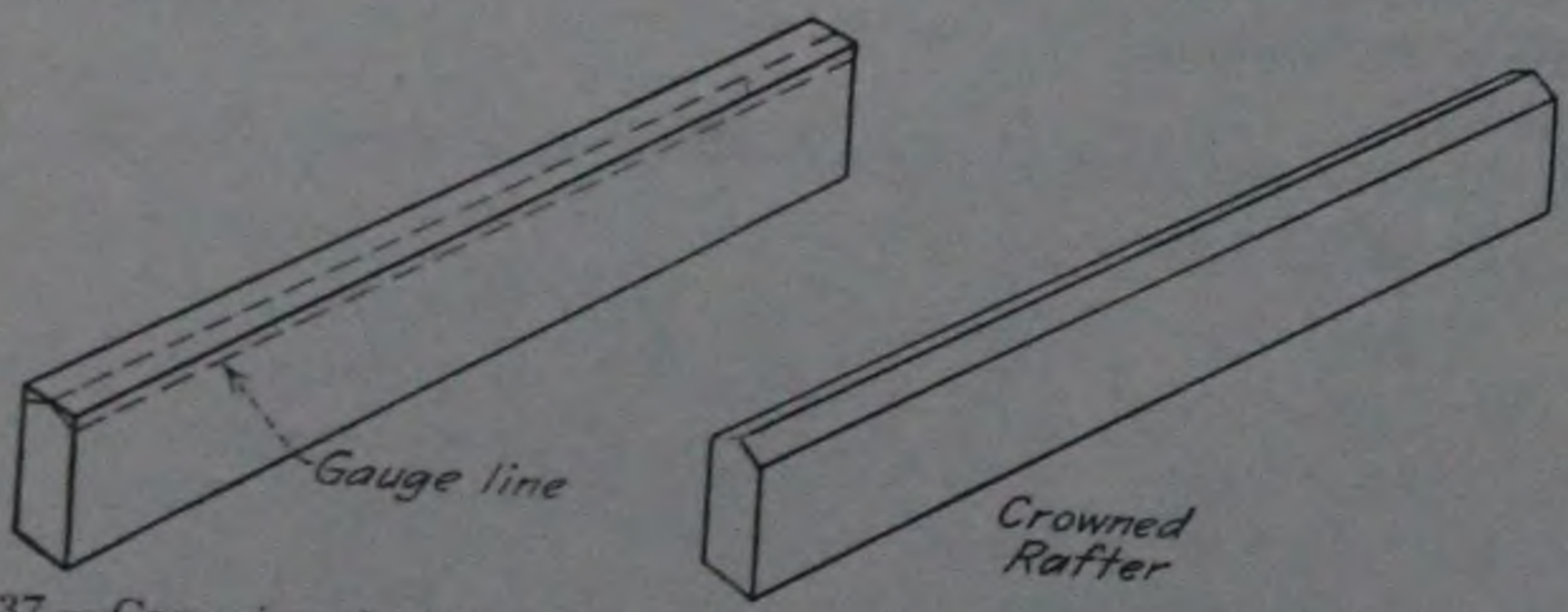


FIG. 137.—Crowning the hip rafter. Where the hip rafter is crowned the setting of the gauge can be secured as shown in Fig. 66.

of a jack rafter is equal to the distance from the center of the rafter at the plate to the corner of the building. If a jack rafter is placed 4 ft. from the corner of the building, then the run will be 4 ft., and if the pitch of the roof is one-third, the rise per foot of run will be 8 in., or the total rise will be 32 in. To lay off the

plumb cut to fit against the hip rafter, proceed as follows: Lay off the length computed for the center of the stock on the long side of the rafter. This will shorten the rafter enough to make up for the thickness of the hip. Draw a plumb line through this point (Fig. 138). The plumb line is the same as for gable rafters of this pitch. Move over horizontally toward the bird's-mouth a distance equal to the thickness of the stock (Fig. 138) at right

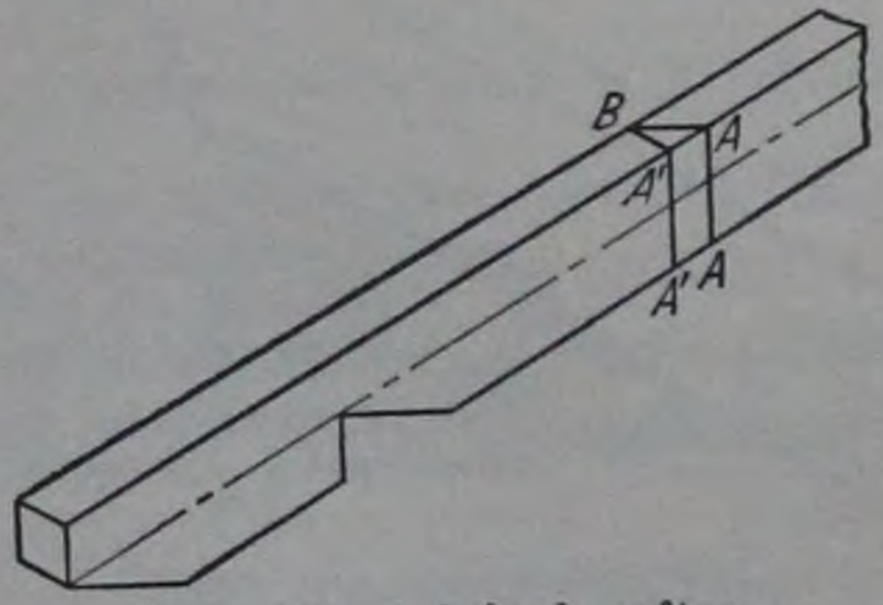


FIG. 138.—A jack rafter.

angles to AA. Square across on top, and draw a diagonal as shown in Fig. 138 $A'B$. By cutting on the lines BA and AA, we secure a pointed cut that allows the rafter to set square across the plate and fit against the hip.

Questions and Problems

137. A building 20 by 36 ft. is to have a ¼-pitch hip roof. How many pairs of gable rafters will be needed in this roof? How many pairs of jack rafters? (Rafters are to be set 2 ft. o.c.) If there is a 12-in. projection on all sides of the building, what length will the hip rafter be, measured on the work line?

138. Make a top view of this roof showing all rafters in place. Use a scale 5 ft. equals 1 in.

PART VI

Buildings for Storage

CHAPTER XXXII

FARM MACHINERY-STORAGE BUILDINGS

We are living in a time known as the *machine age*. Manufacturing has been speeded up and labor requirements reduced by use of more complicated machines, equipped, in many cases, with automatic controls so that they do their work with a minimum of attention. Transportation, mining, agriculture—in fact, every occupation is being mechanized at a rapid rate.

During the last two decades farmers have found it increasingly difficult to secure satisfactory labor. This has forced them to turn to larger capacity machines that enable them to do their work without hiring help. This, together with the need for low cost production, has been the leading influence in the increasing mechanization of farms. Farm-management studies show that machinery makes up 5.8 per cent of the total cost of producing crops; power, 16.6 per cent; and labor, 15.8 per cent.[1] Farmers have recognized the importance of the power and labor items and have been reducing them by increased use of machinery.

193. Importance of Storage.—Where one man cuts and threshes his own grain in one operation, it necessarily follows that the machine he uses must be more complicated than would be required if he were depending to a greater extent on hand labor. This increased complication and resultant cost, together with the fact that the farmer is now dependent on such a machine for the success of his business, increases the importance of storage. The machine must be dependable; it must work when the harvest is ready; otherwise the whole enterprise is at a standstill. No argument is needed to prove that a machine that

[1] Smith, D. D., and M. M. Jones, Power, Labor, and Machine Costs in Crop Production, *Univ. Mo. Agr. Expt. Sta. Res. Bull.* 197, June, 1933.

has been properly housed between seasons will be more dependable than one that is left in the open.

Efficiency in use is usually influenced by storage. A machine that has been allowed to rust and become damaged by exposure may require several hours or even days to smooth up parts until they will operate most efficiently. Many machines are used such a short length of time each year that it is easily possible when they are not properly housed that a large percentage of their work for the year is completed before all parts are working at their highest efficiency.

Inspection of machines should be made during slack seasons and repair parts secured and installed. Fence-corner storage makes this impossible.

Use Factor.—Machines may be used almost continuously in some factory operations. These machines may be worn out in a few years with such use. In this case housing would not be an important factor in management. Since many farm machines are used for only a few eight-hour days each year, storage between seasons is a problem that must be given consideration. When the annual use factor for any machine is low, it is necessary that the life of the machine be extended over a period of years, increasing the importance of care between periods of use.

Replacement cost of machines is sometimes the only factor considered in the question of the economics of storage of machinery. There are two schools of thought on the question: one group for and the other against the investment necessary for storage buildings. It seems that the difference in opinion comes largely from a difference in extensiveness of farming and differences in soil and in climatic conditions in various sections of the country. In some sections the machinery is relatively simple, the use factor is high, and the climate is not destructive. Machinery storage would obviously not be so important under such conditions as it would be under less favorable circumstances.

The following factors are generally considered to determine the life of a farm machine: (*a*) the protection it is given when not in use, (*b*) the degree of carefulness with which it is operated, (*c*) the promptness with which worn parts are replaced, (*d*) the character of the soil, the topography of the land, or the kind of crop in or on which it is used, (*e*) the extent of its use each year, and (*f*) the design and construction of the machine.

In a study of machinery in northwest Missouri, the life and use of machines is reported as shown in Table 43. The estimated decrease in the life of machines due to lack of housing was based upon the opinions of farmers consulted on the question. The percentage reduction due to lack of housing was decreased, somewhat, as a result of the imperfect housing given machines listed in the table as being housed. However, a great majority of the farmers whose farms were studied made a practice of providing some shelter for their machinery.

It has been observed that the repair bill on two machines will not differ greatly if one is housed carefully and used over a period of many years and the other is neglected and worn out in a short time. If there is a difference it will be in favor of the housed machine. Assuming this observation to be true, the machinery cost over a period of 30 years could be computed under two methods of management. A machine shed may be expected to serve for this period, and therefore the amount of money that the farmer would be justified in spending for a building to reduce replacement cost alone can be computed.

In the machinery-cost study mentioned, an annual charge of 3 cts. per sq. ft. of floor space was made for storage. This gives a basis for comparing cost against benefits.

Even though it is not possible to justify an investment in a machine shed from a saving in replacement cost of machines, there are indirect benefits that would justify its construction and use. The farmer, if he is operating efficiently, is frequently in need of credit. If there is any one thing that impresses a banker as poor management, it is neglect of farm machines. A plow left at the end of the last furrow of the previous season or a combine on which there is probably already a loan, neglected in the fence corner, does not make for good credit standing at the bank.

At one time the farmers of America held the balance of power in affairs of government. Today the farmers are in a minority, and it behooves them to keep the good will of people in other occupations if they would have laws made to suit their needs. Careless practices, especially those that may be seen readily, are sure to result in a lack of sympathy for the industry as a whole.

194. Requirements for Storage Buildings.—The requirements for machinery-storage buildings are very limited compared to

TABLE 43.—DATA ON STORAGE OF FARM MACHINES*

Name of machine	Life, years (housed)	First cost	Total repairs during life of machine	Total days used per year	Decrease in life due to not housing, per cent	Storage space required, feet
Mower, 5 ft	20.9	$ 64.58	$ 37.00	8.5	30	6 by 8
Mower, 6 ft	19.1	68.73	33.24	6.4	30	7 by 8
Sulky rake, 12 ft	27.0	30.40	0.27	3.2	24	6 by 12
Sweep rake	18.7	36.65	20.76	6.7	24	10 by 12
Stacker, overshot	24.4	44.05	27.82	7.0	31	
Hay loader	25.0	90.00	28.50	6.0	37	9 by 10½
Walking plow, 14 in.	26.8	16.82	25.19	3.7	20	2 by 7
Sulky plow, 16 in.	22.5	55.17	41.40	13.4	22	3 by 9
Gang plow, 2-14 in.	24.0	66.66	63.20	10.0	22	5 by 9
Tractor plow, 2-14 in.	14.3	112.75	47.19	9.8	14	7½ by 12
Spike-tooth harrow, two section	20.0	16.98	2.60	6.7	8	3 by 5
Single disk, 7 ft	21.0	47.08	17.64	8.2	30	8 by 4
Tandem disk, 7 ft	18.0	113.57	19.26	10.9	30	8 by 8
Roller	21.8	69.00	2.18	3.2	15	8 by 3
Corn planter	18.1	75.90	14.30	5.2	32	6 by 5
Corn cultivator, 1 row	21.0	39.68	24.57	11.9	20	6 by 8
2 row	20.0	87.85	25.60	12.1	20	7½ by 7
Rotary hoe, 2 row	14.3	81.50	4.00	7.2	24	8 by 3
Corn binder	19.4	161.87	39.58	4.8	36	9 by 8
Silage cutter	21.5	442.50	83.20	4.3	15	7 by 12
Endgate seeder	19.5	27.48	0.78	1.4	38	3 by 5
Grain drill, 10 hole	24.0	96.50	24.00	9.0	38	5 by 12
Grain binder, 6 ft	27.3	133.33	31.67	4.0	33	9 by 13
Grain binder, 7 ft	18.3	188.18	39.35	5.1	33	9 by 14
Grain binder, 8 ft	14.5	223.33	28.42	4.3	21	10 by 16
Wagon	28.2	71.29	36.10	43.6	30	7 by 14
Manure spreader	21.1	124.84	16.67	15.7	30	8 by 14
Lime spreader	16.6	57.00	2.32	1.5	38	3 by 4
Feed grinder, 6-in. burr	23.5	27.50	23.50	5.0	21	3 by 3
Gas engine	17.0	54.00	6.29	14.4	5	3 by 3
Tractor						7 by 12
Automobile						8 by 16
Combine, 5 ft	15.0	600.00	125.00	10.0	25	10 by 14
Combine, 10 ft	10.0	1200.00	245.00	12.0	25	12 by 15
Combine, 12 ft	10.0	1500.00	358.00	16.0	25	15 by 20

* SMITH, D. D., and M. M. JONES, *Univ. Mo. Agr. Expt. Sta. Research Bull.* 197, June, 1933.

those for animal shelters. Machines should be kept dry; the storage building should be tight enough to exclude birds, poultry, etc., and should be convenient for storing and removing machines. A concrete floor is desirable, although not essential. It aids in keeping machinery dry and makes handling much less difficult.

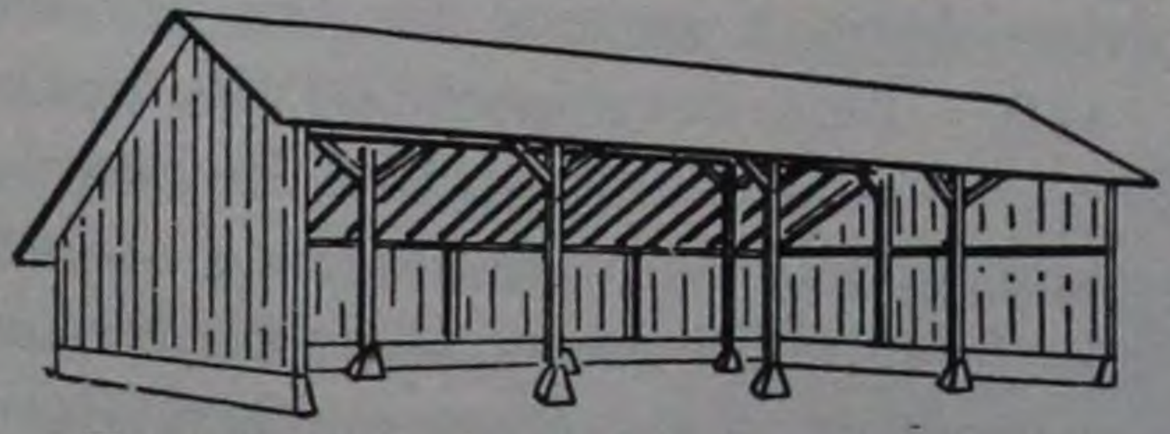


FIG. 139.—An open-front storage shed.

Heavy machines settle into loose-earth floors, and parts near the ground may rust considerably. If the floor is damp machines should be blocked up to prevent damage. Packed clay, if it is graded to drain well, crushed rock or gravel, or stabilized earth may be used satisfactorily for machine-shed floors. A good

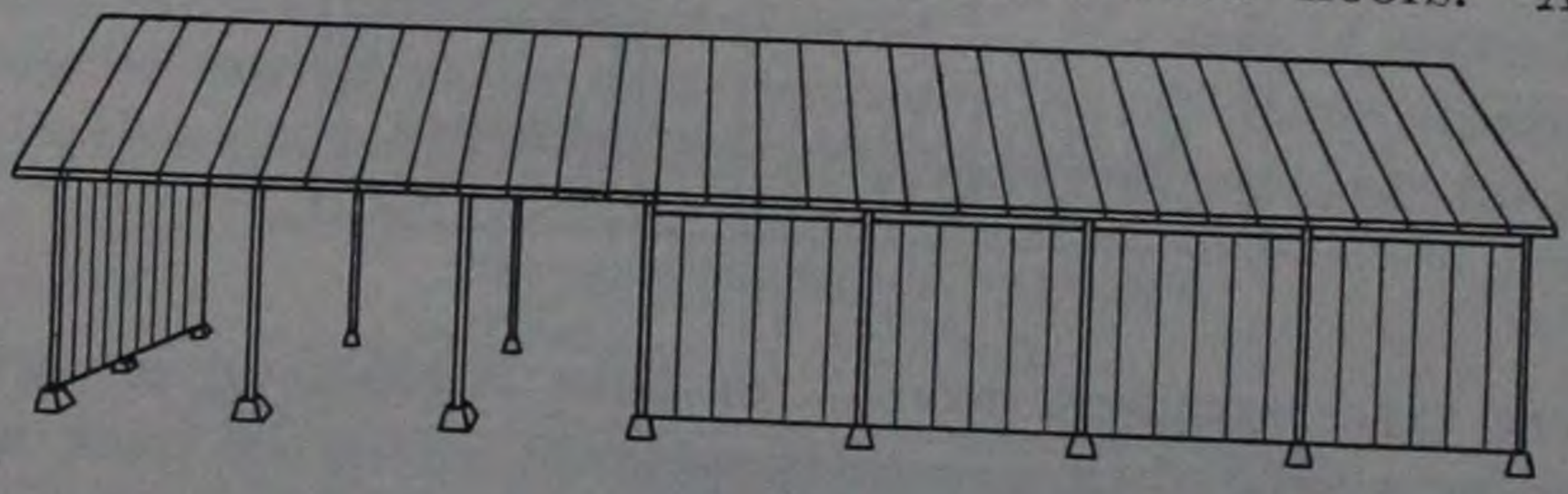


FIG. 140.—A closed shed with drive-through section.

floor will pay for itself by easing the task of storing and removing machines from storage.

Storage of Equipment Used Frequently.—An open-front storage house is often used for wagons, manure spreaders, etc., that are used frequently. A shed open to the east is probably most

desirable where it can be used. A depth of 14 or 16 ft. can be used where machines are backed into stalls. The length will depend on the amount of equipment to be stored (see Fig. 139).

Storage of Field Machinery.—A combination house containing space that is enclosed for the machines used during a short season and a drive-through section for trucks, wagons, etc., is shown in Fig. 140. This open section will not provide such good conditions as the closed section, but the convenience offered will probably result in the equipment being stored most of the time, whereas the inconvenience of the closed storage might be the cause of its being left in the open much of the time.

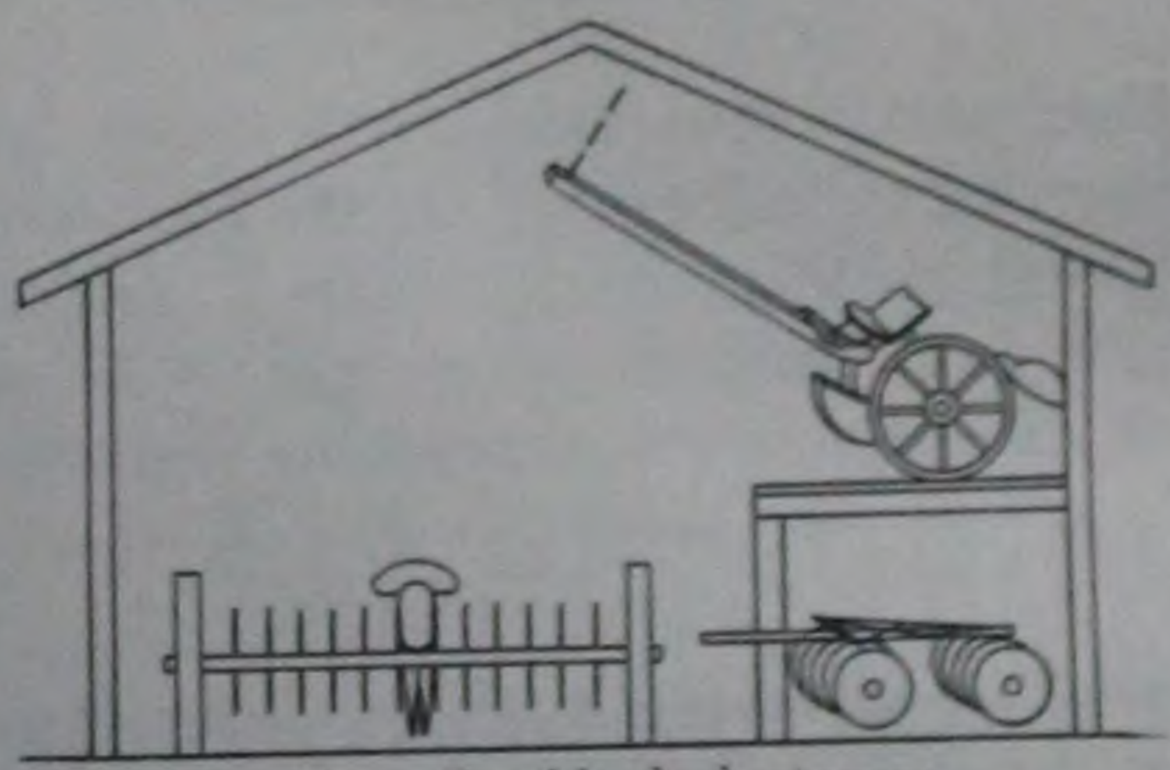


FIG. 141.—Double-deck storage.

Where extra space is needed for light equipment, a narrow balcony or a wide shelf is sometimes built along the back wall. If it is made 4 ft. high and 5 or more ft. wide, some machines can be stored under and some on this platform. If doors are provided for driving through, the platform may be built on one side of the drive where machines may be transferred from a wagon directly to the platform (see Fig. 141).

The combine, especially the larger size, creates a problem in storage. It is too valuable a machine to leave in the open, and most owners do not wish to disassemble it for storage because of the danger that parts may be lost and delay at harvest time result. To store the combine, a building with wide doors and no center posts is needed. In certain sections in Kansas and Oklahoma large semicircular-roofed storage buildings have been constructed (see Fig. 142). Some farmers use these sheds for storing wheat, simply putting the wheat in a large pile on the floor. If the farmer has his own truck he can take his time to market the crop.

Since machinery and horses are used together, it has been suggested that they be housed in the same structure.

195. The Farm Shop.—A repair shop may be built into one end of the machine shed. When not in use as a shop, the space can be used for storage of easily moved machinery. The stove, forge, bench grinder, and drill press, together with cabinets for tools, may be arranged to be convenient for work and yet be out of the way for storage of machines. Figure 140 shows such an arrangement. The shop is located beside the drive-through section, which makes it very convenient for summer work.

Fig. 142.—Semicircular roofed storage building.

The shop and garage may be combined in some cases. The stove is one of the first essentials for the farm shop. Repair or construction work can be done in the winter season if a comfortable place to work can be provided. If space is needed, the car can be moved easily and machines moved in or equipment built in this space. Winter days that are less valuable for other work may be made effective by having equipment and machines in condition to use when the busy season arrives. Figure 143 shows a combination farm shop and garage 14 by 20 ft. The shop is equipped with a bench and vise, stove, forge and anvil, drill press, an emery grinder, and such other equipment as is needed. Most farms have a fair assortment of tools that would be much more useful if there were a shop where they could be

Fig. 143.—Combination farm shop and garage.

conditioned, stored, and used. A saw filed on a winter day saves expense and saves time when it is needed at a later date.

Questions and Problems

139. "Farmers are becoming increasingly dependent on machinery." Is this statement correct? Explain fully.

140. This dependence increases the necessity for housing machines between seasons. Why is this true?

141. One farmer suggests that instead of storing machinery in a storage building, heavy oil on all working parts at the end of each working season would be adequate protection for the machinery. Is this a correct solution for the problem?

142. Make a list of the machinery used on a farm with which you are familiar. Figure the cost of owning each machine for a 30-year period without housing; with proper housing.

143. If a machinery-storage building cost 3 cts. per sq. ft. per year, what would the farmer gain or lose by owning a machine shed?

144. From your list (question 142) select (*a*) the five machines that will benefit most from proper housing and (*b*) the five machines that will benefit least.

145. Could farm machinery be designed so that it would not need housing? Illustrate.

CHAPTER XXXIII

HAY- AND GRAIN-STORAGE BUILDINGS

196. Hay Storage.—The method of putting hay in storage is a factor to be considered in planning hay-storage buildings. For many years it was customary to pitch hay by hand from the wagon into the loft of the barn. This practice probably started the custom of providing a central driveway in the barn. With the development of power haying tools, forks, carriers, etc., it became just as convenient to take the hay in at the end of the barn, and the necessity for a central driveway was thus eliminated. A large door at the end of the barn and a projecting roof are used to facilitate storage of hay by this method. When the sling method of handling hay supplanted the fork method, still larger hay doors and a stronger carrier track were necessary. The conventional method of storage provides space for loose hay over the stable or livestock room. Sufficient strength is built into the structure to support this load, the expense being justified by the convenience in feeding and the insulating value furnished by the hay. Where less expensive storage is desired, the space for hay can be located in the center of the barn extending to the ground, with sheds on either side to provide space for livestock. This may not be so convenient for feeding as the overhead storage, but even though the roof area is increased, it is usually found to be the cheaper plan. Baling hay either from stacks or field storage barns or direct from the windrow brings in some new storage problems. Barns for loose hay are usually not well adapted to storage of baled hay unless some modification is made, both for getting hay into the barn and for strength if additional amounts are stored.

The practice of chopping hay and blowing it into the mow is becoming more and more popular. Only a very small opening into the mow is required for the entrance of the blower delivery pipe, and the central storage space may be reduced both in width and height as compared to the space required for loose hay, since from one-third to one-half the mow space formerly

required is necessary in this method of storage. The arrangement and design of chutes for the most convenient handling of chopped hay is somewhat different, however, than for the long hay. If chopped hay is stored in an overhead mow some strengthening of the structure will be necessary. This may be

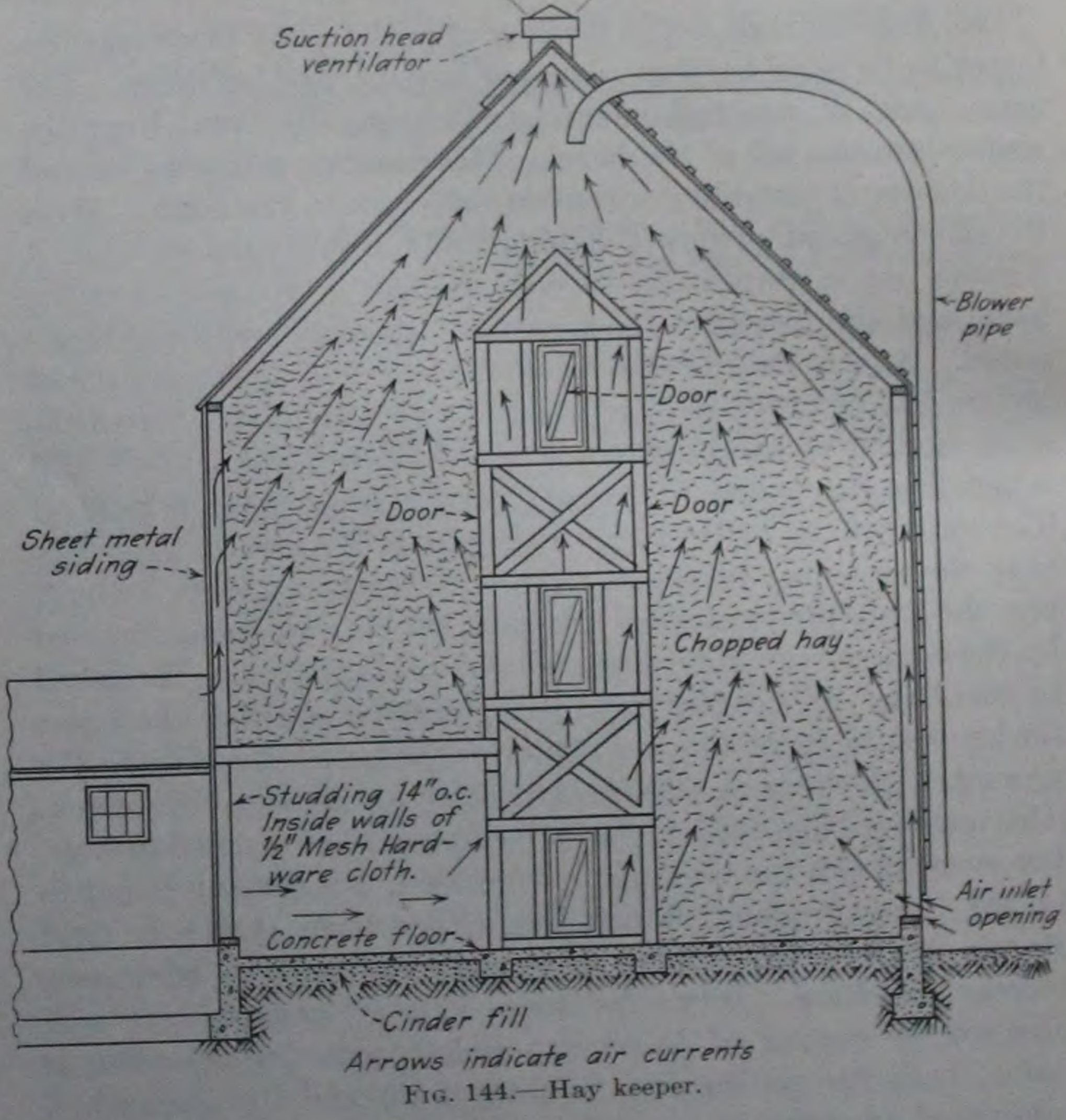


FIG. 144.—Hay keeper.

accomplished by shortening spans or by increasing the size or number of other members.

The practice of chopping hay has led to the development of a new type of hay-storage structure known as the *hay keeper* (see Fig. 144). This building is usually made circular for the sake of economy and strength. A weatherproof covering is placed outside, and wire netting similar to hardware cloth is placed

inside the studding. An opening in the siding at the bottom of the studding admits outside air, providing circulation in the space between the studs. Any heat generated in the hay or absorbed through the siding will cause extra draft in this space. The hay is thrown down a center chute that is made from 4 to 6 ft. square. This chute must be well braced and is covered with hardware cloth to allow for additional circulation of air through the hay. A tunnel is made to connect the center chute with the feed alley. A suction-head ventilator completes the ventilation equipment for the structure. The James Manufacturing Company of Fort Atkinson, Wis., are originators of this type of structure. The building shown in Fig. 144 is 24 ft. in diameter and 20 ft. high with a 5- by 5-ft. center chute and will hold about 65 tons of cut hay.

On some farms a definite attempt is made to decrease the labor required to care for the hay at harvest time. The hay is stacked in the field or in storage barns located in the field. No time, therefore, is lost in hauling the hay to the farmstead at the harvest season, this work being postponed until winter, when other work is not rushing. Figure 145 illustrates a barn designed for hay storage alone, no provision being made for feeding at the barn.

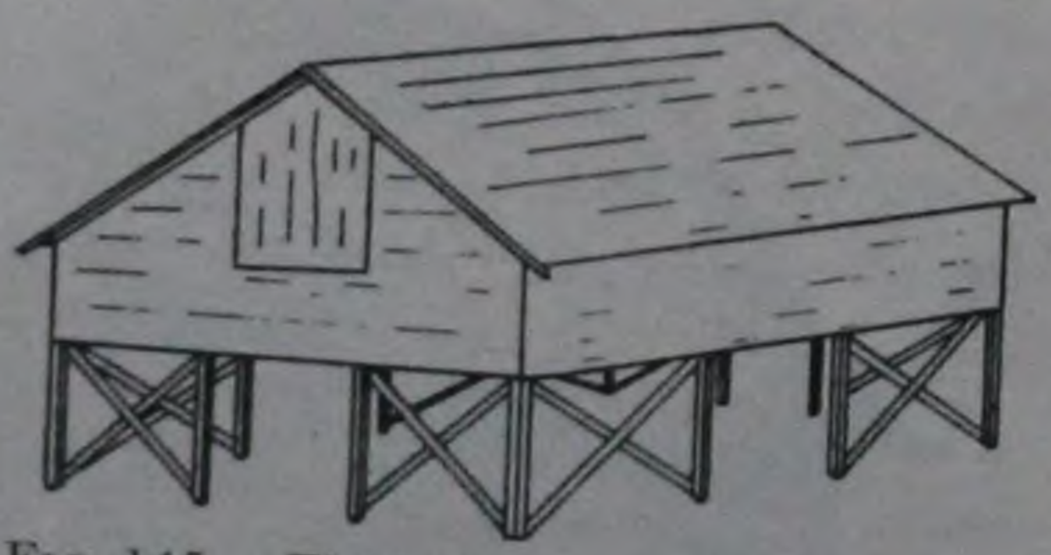


FIG. 145.—Field storage barn for hay.

With this method of handling hay it is necessary to provide space in the animal shelters for at least 2 weeks' feed storage; and all through the winter season at intervals of 2 weeks it will be necessary to haul hay from the field barns or stacks and supply the feeding barns.

C. P. Wagner, agricultural engineer with the U.S. Rural Electrification Administration, has made some studies on the cost of putting hay into storage by different methods. During a recent season 100 haying crews storing hay with forks and slings were timed. They averaged 21 min. 46 sec. to the load. The same 100 crews were timed putting up hay by the stationary-chopper method. They averaged 15 min. 10 sec. per load. The average five-man crew handled two loads of long hay per hour. With one man less on the job the chopped hay went

under cover at the rate of three loads per hour. Savings made possible by the chopper method frequently ran as much as 40 cts. per ton handled. The following comment from an experienced operator is typical: "For ten years we have put up all our feeding hay by the chopper system and our market hay by fork and track. In chopping hay we load two wagons and then come

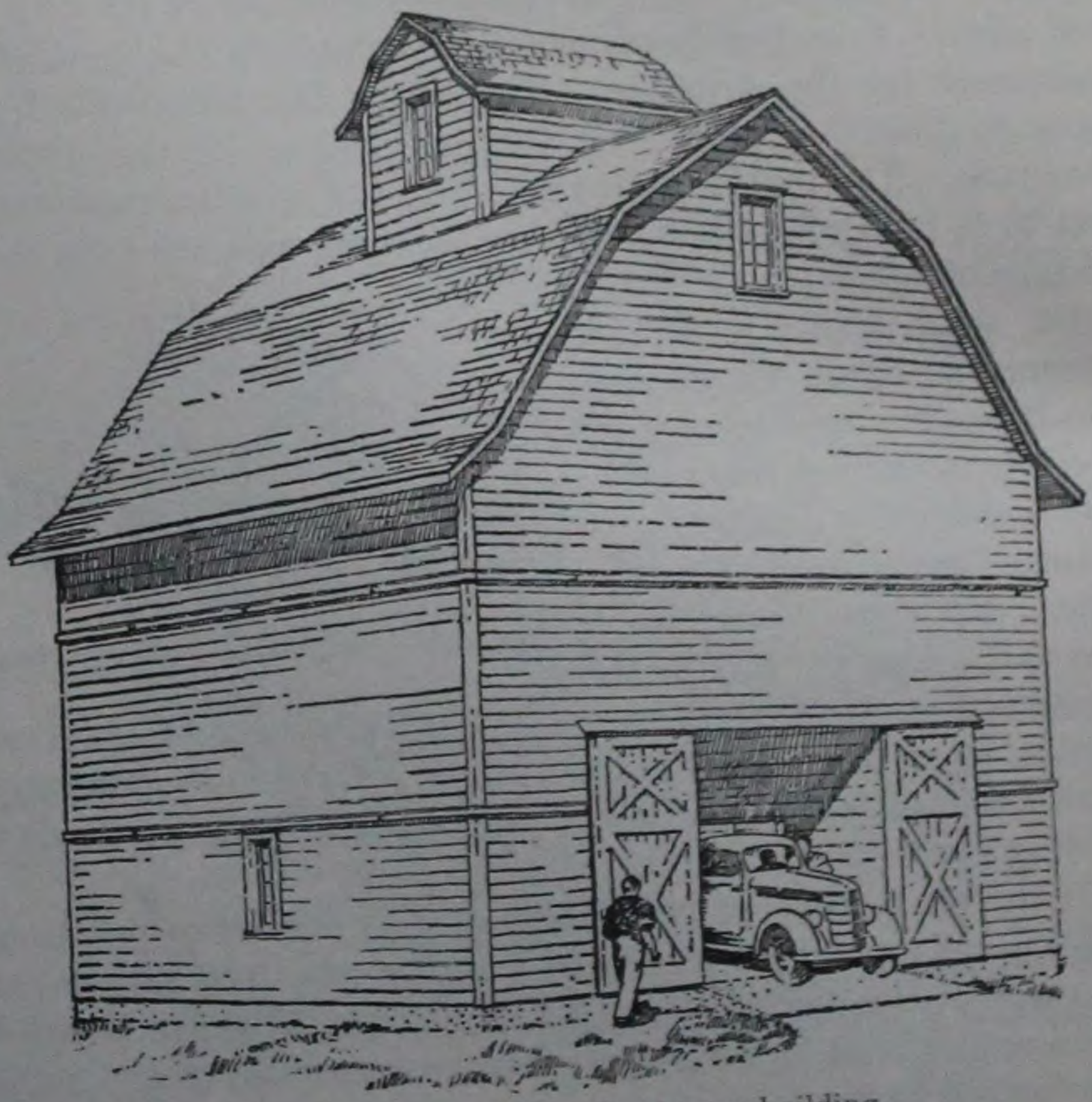


FIG. 146.—A central grain-storage building.

in and cut off both loads. With two of us on the load and a third man on the platform beside the feed table, we are able to put a ton through in from six to ten minutes."

197. Grain Storage.—There are two general methods of storing grain on the farm. In one method a central storage building is used (see Fig. 146), and in the other grain is distributed at harvest into cribs or bins located in different buildings according to the needs of the animals housed there.

In the *central storage system* grain fed on the farm must be loaded and hauled to the different points at which it is needed at frequent intervals throughout the year. The storage building may be equipped with an elevator and dump so that grain can be stored easily. By use of hopper bins and an elevator, it is possible to move grain from one bin to another in case of heating; or it is possible to move it into the sheller or grinder for processing or into trucks for delivery to feed bunks or to a purchaser in case of sale. Central storage has some disadvantages, the principal one being the extra fire risk that results from the concentration of the whole crop in one building. It has some advantages where grain is processed before it is fed and, again, where power equipment is used in handling it.

When grain is *distributed* at harvest into cribs or bins located in different buildings where it is to be used, the labor at that particular time is greater than in the central storage method, but the convenience of having the grain distributed at points at which it is needed may offset this disadvantage. Since an outside portable elevator is readily and easily moved, it is valuable in storing grain in distributed storage buildings.

The Agricultural Adjustment Act of 1938 provides an ever-normal granary plan for wheat. This program includes acreage allotments, crop insurance, commodity loans, and, in time of burdensome surpluses, marketing quotas.[1]

The conditions set forth for the storage of wheat under the ever-normal granary program are as follows: The bin or granary used for the storage of wheat should be a substantial and permanent structure that will (*a*) hold wheat without loss of quantity, (*b*) protect the wheat against weather conditions that would cause deterioration in quality, (*c*) afford reasonable protection against thieves, rodents, birds, poultry, and insects, (*d*) permit effective fumigation for the destruction of insects, (*e*) provide reasonable safety from wind and fire, and (*f*) require forcible breaking in order to be entered when sealed.

Rapid deterioration of damp wheat in storage is usually caused by the activity of microorganisms and by excessive respiration of the wheat kernel. Heat is evolved both by ever-present microorganisms and by kernel respiration at a rate depending to a

[1] Wheat: Wheat Storage in the Ever-normal Granary, Commodity Information Series issued by U.S. Department of Agriculture, May, 1938.

large extent on the wheat moisture content and wheat temperature. Where the heat generated by excessive respiration is not removed promptly it will raise the wheat temperature and increase the rate of respiration. Unless the heat and excess moisture are removed, this self-accelerating process will continue until the grain is unfit for human consumption.

The maximum safe moisture content for long-time storage in nonventilated farm structures varies in the different wheat-growing areas, depending on weather conditions, the kind of wheat, the grade and condition of the wheat when stored, and the

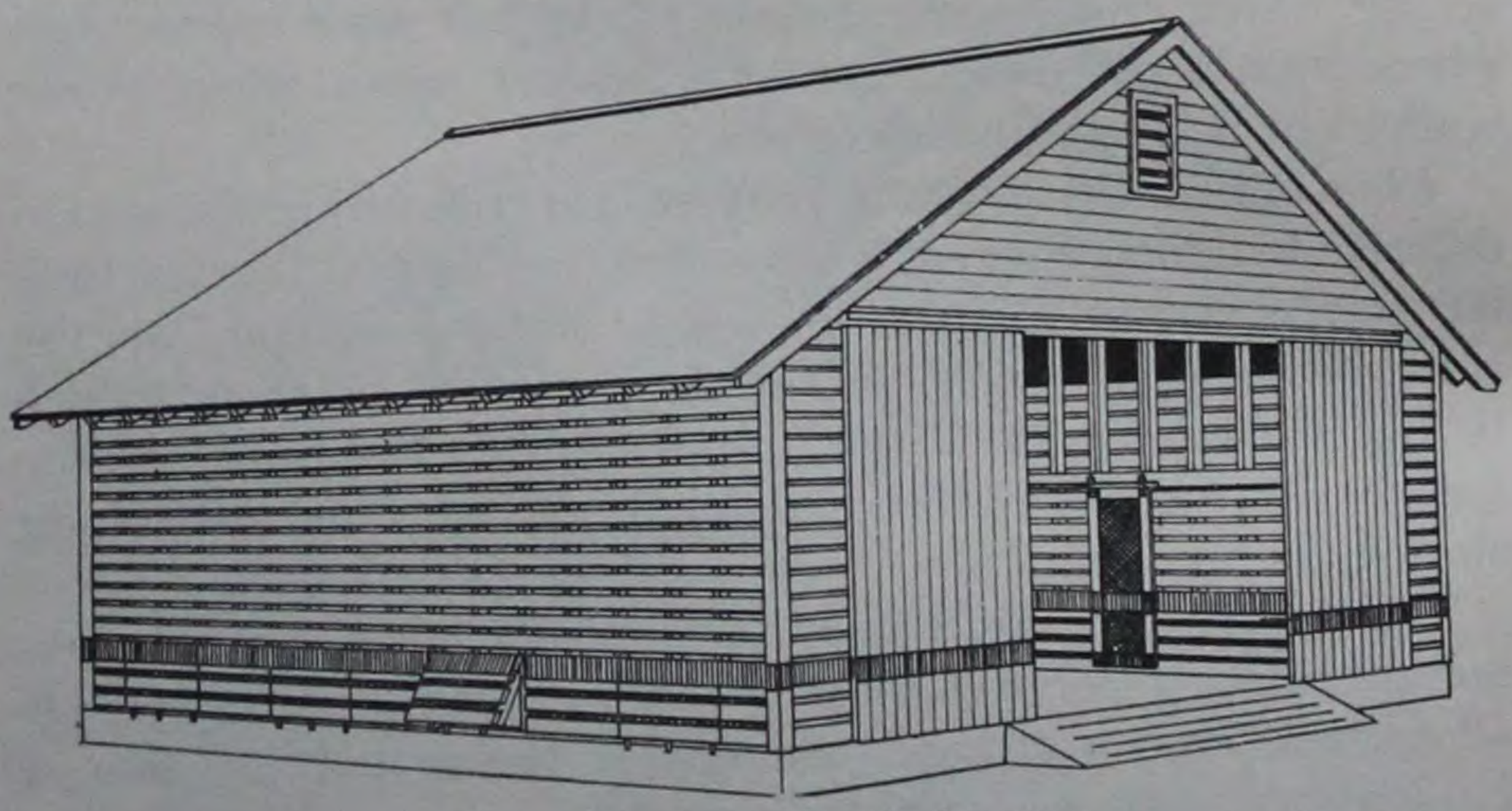


FIG. 147.—A double crib for corn.

length of time the wheat is to be held, but, in general, it may be said to be from 13 to 14 per cent.[1]

The Agricultural Adjustment Act of 1938 provides also an ever-normal granary plan for corn.[2] The requirements for corn storage under this plan are stated briefly as follows: Cribs must provide adequate ventilation facilities to condition the corn properly and be so located and of such substantial construction as is necessary to afford protection against weather and rodents for a period of not less than 2 years.

198. Cribs and Bins.—Where grain is shoveled from the wagons into the bins by hand, the height of bin is limited to 12 or perhaps 14 ft. (see Fig. 147). If the grain is handled by means

[1] KELLEY, C. F., Methods of Ventilating Wheat in Farm Storages, *U.S. Dept. Agr. Circ.* 544.

[2] Corn: Corn Storage in the Ever-normal Granary, Commodity Information Series issued by U.S. Department of Agriculture, June, 1938.

of elevators, the height of bin is limited only by the type of elevating equipment and the type of structure used (see Fig. 146).

The design of grain bins, especially in the larger sizes, calls for careful computations of lateral pressures, loads on floors, and loads on walls. Janssen's formula[1] is widely used in computing lateral pressures (outward thrust) on bin walls. The formula is

$$L = \frac{WR}{f}\left(1 - \frac{1}{2.718^{\frac{kfh}{R}}}\right) \qquad (42)$$

where L = lateral pressure in pounds per sq. ft.
W = weight of grain in pounds per cubic feet.[2]
R = the hydraulic radius of the bin (cross-sectional area ÷ perimeter).
f = the coefficient of friction of grain on bin walls.
k = ratio of lateral to vertical pressure.
h = the depth of grain at any point.

In the application of this formula it is necessary to have values for f and k for the different grains and different types of walls. These values have been determined experimentally and are given in Table 44.

TABLE 44.—DATA FOR COMPUTING PRESSURES IN GRAIN BINS*

Kind of grain	Rough boards		Smooth boards		Galvanized iron		Concrete	
	f	*k*	*f*	*k*	*f*	*k*	*f*	*k*
Wheat	0.450	0.450	0.400	0.380	0.468		0.425	0.600
Barley	0.424	0.450	0.325	0.380	0.376		0.452	
Oats	0.450	0.450	0.369	0.380	0.412		0.466	
Shelled corn	0.344	0.450	0.308	0.380	0.374		0.423	
Beans	0.435	0.450	0.322	0.380	0.366		0.442	
Flaxseed	0.407	0.555	0.308	0.500	0.339		0.414	
Rye	0.540	0.300	0.460	0.300			0.850	0.300

* LONG, J. D., *Agr. Eng. J.*, Vol. 12, No. 7, p. 274, July, 1931.

An appreciable amount of the weight of the contents of a bin is carried on the side walls. In deep bins it is by far the greater amount of the load. For bins with a depth greater than 2½ times the diameter, the weight carried by the side walls may be

[1] LONG, J. D., *Agr. Eng. J.*, Vol. 12, No. 7, p. 274, July, 1931.
[2] See Table 37, p. 227.

determined approximately by multiplying the total inside-wall area by the average lateral pressure and this by the proper coefficient of friction. Floor pressures would, of course, be the total weight of the grain minus the weight transferred to the walls by friction.

Floors may be of wood, concrete, or tile. If made of wood, the floor should be located well above ground to prevent rotting and to keep the grain away from soil moisture. Some feeders build their cribs with the floor 3 ft. from the ground to provide a place

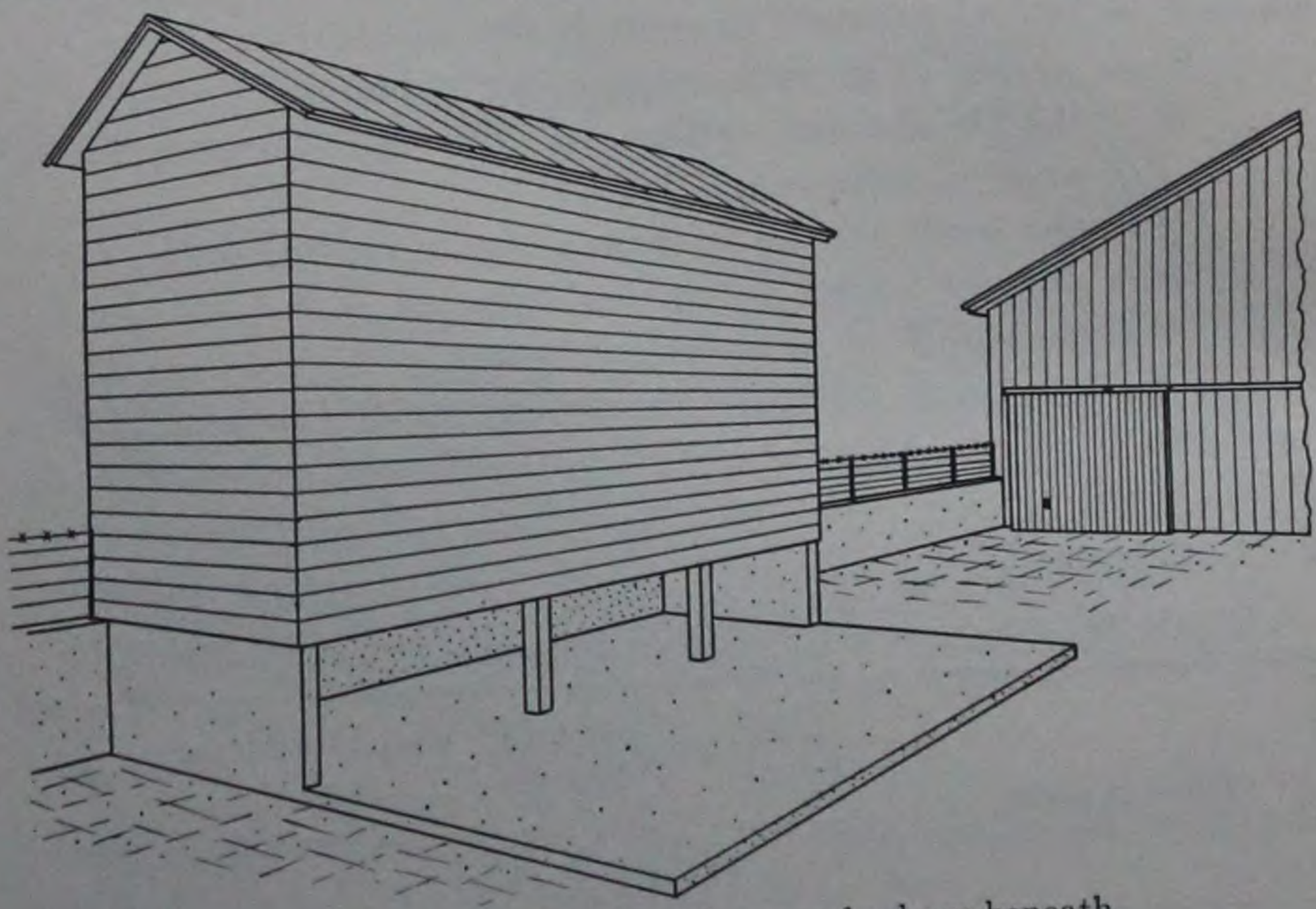


Fig. 148.—A single crib with space for hogs beneath.

for stock hogs under them (see Fig. 148). Tight floors are necessary in this case to prevent dust from reaching the corn. Reinforced concrete floors may be used in this way, or they may be placed directly on a fill. A 6-in. layer of screened gravel under the floor is usually sufficient to keep it dry. A tar coating on the ground under the fill or a tar-paper covering is sometimes used in a similar manner to cut off capillary moisture from below. Building or floor blocks laid on a sand bed and then covered with a thin layer of concrete make a desirable floor. Number 2 grade drain tile may be used in a similar manner to provide an air space under the floor.

Where the floor is tight a section of hardware cloth about 30 in. wide is nailed inside the siding. On the outside of the studs near

the top of this cloth a piece of metal is fastened horizontally to serve as a rat fender. Where cribs are not in contact with other buildings rats and mice are thus prevented from entering.

As a general rule, wider cribs can be used in the southern edge of the corn belt because of better drying conditions in the fall and a longer drying season. Crib widths vary from 5½ ft. in the north to 12 ft. in the southern edge of the corn belt.

Ventilation for the stored corn is provided by using slatted siding of wood or special perforated tile or metal. A shelling

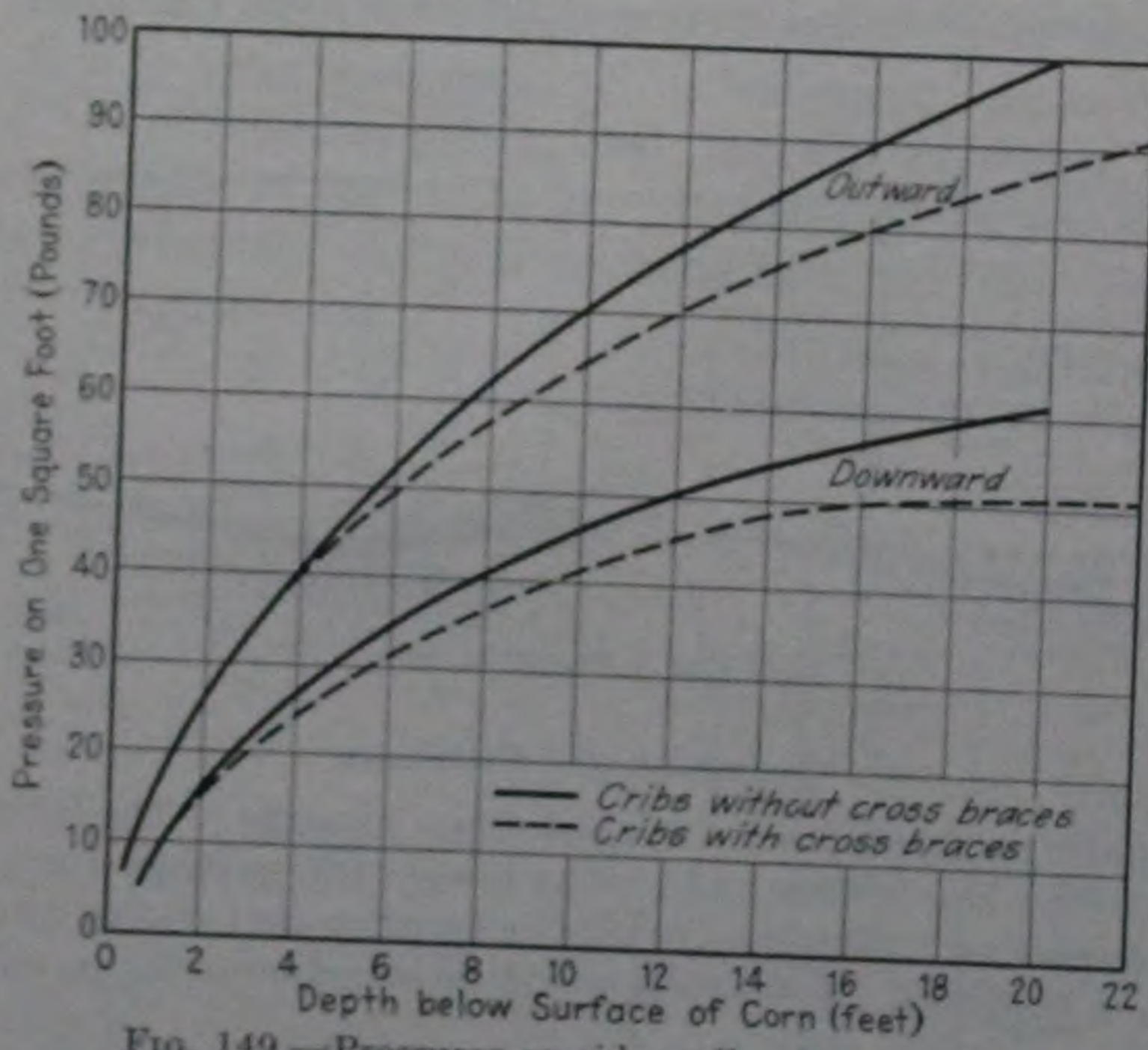


FIG. 149.—Pressures on side walls of corn cribs.

trench placed in the floor aids in ventilation, and by inserting a drag elevator the corn can be removed with a minimum of scooping.

Design of Cribs for Ear Corn.—The pressure on the side walls of a crib depends upon a number of factors: the weight of the corn, the percentage of husks left on the corn, the width of the crib, the frequency of cross braces, and the rate of filling. If corn is added slowly the mass in the crib has time to settle and become stable before complete filling is accomplished. Cribs that are filled in one or two days, as is often done with mechanical pickers, are subjected to greater strain than would be the case if the filling extended over a period of 2 weeks. The curves shown in

Fig. 149 enable the designer to determine the outward and the downward thrust on the side walls of a crib up to a depth of 22 ft.[1] The floor pressure in the crib will be equal to the total weight of the corn minus the downward thrust exerted on the walls.

Portable bins or cribs are not used so much for corn as they are for small grain. Small grains are sometimes threshed directly into portable bins placed beside the thresher at threshing time, and the grain is fed from this point or perhaps stored for later sale. Movable cribs may have greater value with the development and use of corn-harvesting machinery (see Fig. 150).

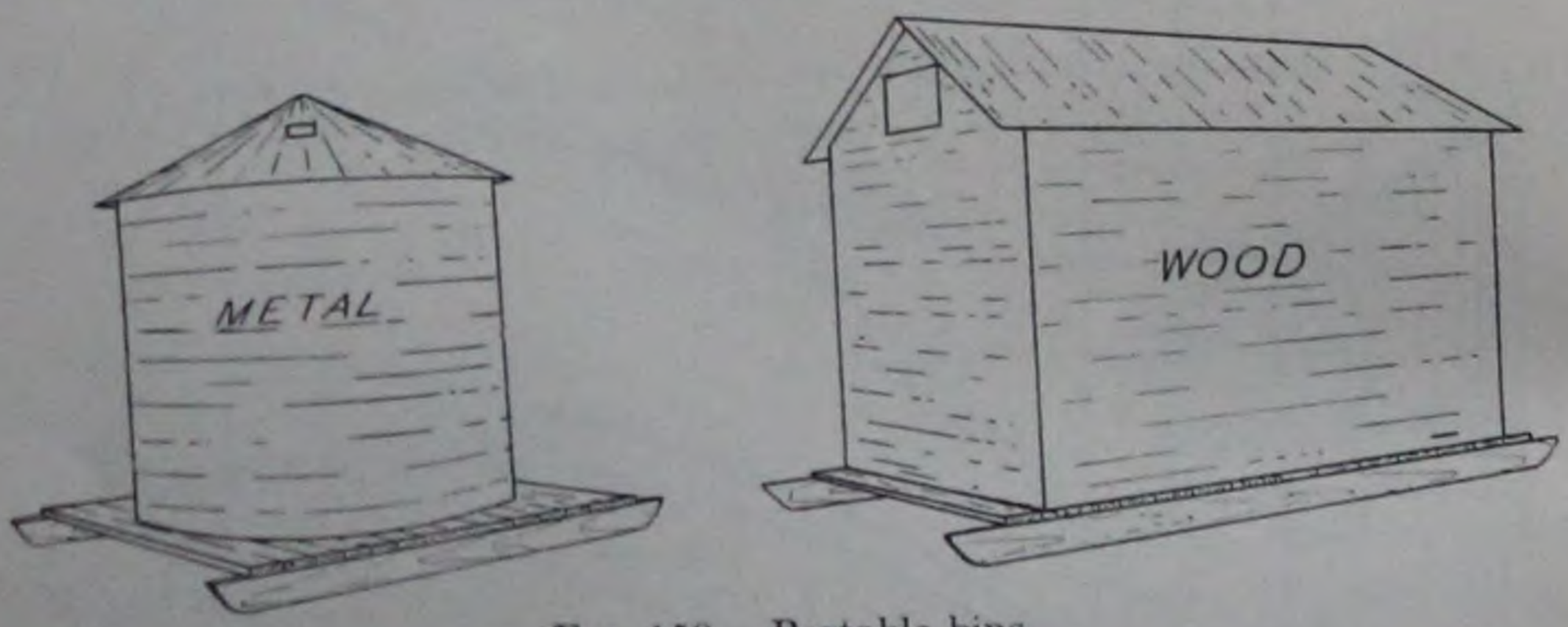


Fig. 150.—Portable bins.

Questions and Problems

146. A farm produces about 100 tons of hay annually. The farm is to be equipped with a hay-storage and feeding barn. Hay-storage space will cost 3 cts. per cubic foot. How much would be saved on the building by adopting the chopper method? How much would be saved annually in storing the hay?

147. What advantages does the "hay keeper" have over regular storage? Explain fully.

148. Hay harvest has caused one of the peak demands for labor in the past. What can be done to avoid this?

149. A 12- by 32-ft. concrete silo is to be filled with wheat. How many bushels will it hold? What would be the lateral pressure on the lower 1 ft. of the wall?

150. If the wall of the silo is 5 in. thick, what would be the load per square inch of the wall at the base? How much load would be added by friction of the barley on the walls? Would the total load be too great for safety?

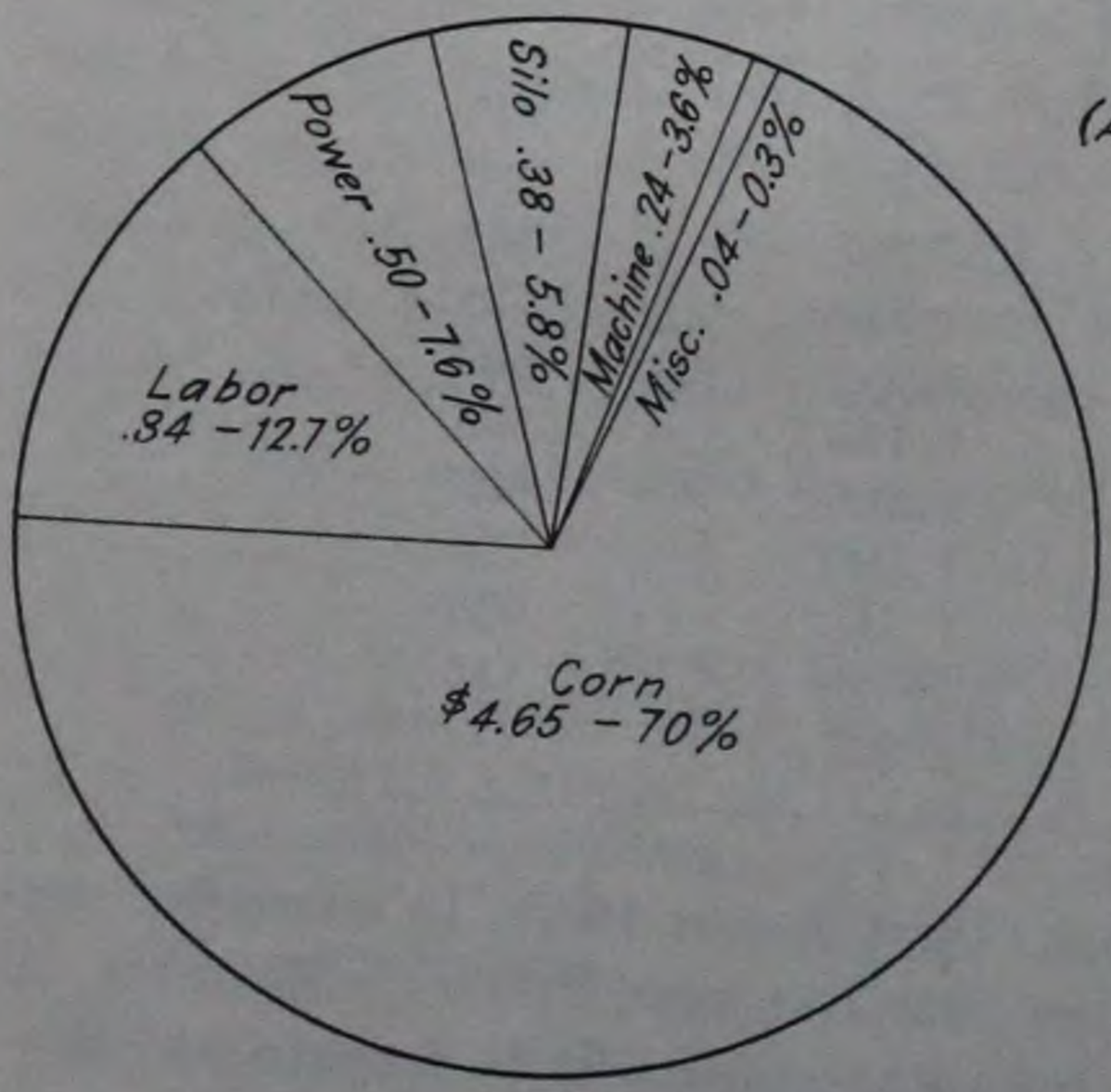
151. A crib 8 ft. wide and 14 ft. high is filled with ear corn. Studding 2 by 6 in. are placed 2 ft. o.c. The studding are fastened to the floor joists by five 20d spikes clinched. Would the nailed joint be safe?

[1] McCalmont, J. R., and Wallace Ashby, Pressures and Loads of Ear Corn in Cribs, *Agr. Eng. J.*, Vol. 15, No. 4, April, 1934.

CHAPTER XXXIV

THE SILO

199. Advantages of a Silo.—Not every farmer will find a silo to be essential on his farm, but in a majority of cases it will enable him to increase the size of his business. On farms having a need for succulent winter feed the silo furnishes the most practical means of supplying it. If there is danger of pasture shortage during the summer months, the silo may be used to



Silage Costs
(Average of 152 Mo. Farms)

Item	Cost per Ton	Per Cent
Corn	$4.65	70.0
Labor	.84	12.7
Power	.50	7.6
Silo	.38	5.8
Mach.	.24	3.6
Misc.	.04	0.3
Total	$6.65	100%

FIG. 151.—The cost of silage.

tide over this period without loss in production. On a farm where lack of roughage is a limiting factor, the silo overcomes this handicap and increases the livestock-carrying capacity of the farm. Where the supply of roughage is uncertain, the silo provides a means of holding a crop over from a year of plenty to a time of need. In case of hot winds or early frosts the silo provides a means of saving a crop that would otherwise be lost. Where fall wheat is grown following corn, the removal of the corn for silage facilitates fall seeding. During stormy periods in winter the silo is appreciated for the convenience it affords.

These benefits must be balanced against the annual cost of the silo, the cost of labor, the power and machinery involved, and the value of the crop used for silage (see Fig. 151 for cost data on silos and silage).[1]

200. Size of Silo Needed.—The correct diameter is of great importance to the success of the silo. If the diameter is too great the silage will be exposed for too long a period before it is fed; and unless a quantity is thrown away each day, tainted silage will be fed at all times. A farmer having 14 cows, with the usual complement of young stock, built a silo 18 ft. in diameter and 24 ft. high. He filled it one year but says that he will never fill it again. His opinion is that silage is not fit to feed to any animal, let alone a dairy cow. He was probably right in his case, because he could not feed a sufficient amount each day and, consequently, was always feeding spoiled silage. Under Missouri conditions it has been found necessary to remove 1½ in. of silage per day in winter and 3 in. per day in summer to keep the silage from spoiling. Table 45 gives this quantity in pounds. Therefore, it can be said that the diameter of the silo depends upon two factors, (*a*) the amount of silage fed per day, and (*b*) the time of year in which the feeding is being done.

TABLE 45.—POUNDS OF SILAGE THAT MUST BE FED DAILY TO KEEP SILAGE FRESH

Diameter of silo, feet	Summer, 3 in. daily	Winter, 1½ in. daily
8	452	226
9	573	287
10	707	354
11	855	428
12	1,018	509
13	1,195	598
14	1,385	693
15	1,590	795
16	1,810	905
18	2,290	1,145
20	2,827	1,414

[1] JONES, M. M., and D. D. SMITH, Silo Filling Methods and Costs, *Univ. Mo. Agr. Expt. Sta, Bull.* 303, 1931.

If the amount and kind of livestock to be fed and the season of the year are known, the daily silage needs may be computed. Table 46 gives the feeding rates for different livestock.

When the daily requirements have been computed and the weight per cubic foot of silage is known, the proper diameter can be determined. The weight per cubic foot of silage varies considerably, but for average corn silage 36 lb. per cubic foot is a satisfactory figure. Silage may be heavier than 36 lb. if it is located near the bottom of a tall silo, but as the silage is removed the surface layer expands somewhat, and the 36 lb. per cubic foot is a good average figure to use in solving feeding problems. Capacities for silos of different depths and diameters may be determined from Fig. 152. The data on weight per cubic foot were obtained by weighing the silage as it was used.

When the depth of silage needed to feed through the season has been determined, add 5 or 6 ft. to this figure to secure the proper height of silo to build. This allows for settling. Although the height of silo needed is governed by the length of the feeding period, the maximum height should not usually exceed 2½ or 3 times the diameter of the silo.

TABLE 46.– FEEDING RATES FOR DIFFERENT LIVESTOCK

Kind of Livestock	Amount Silage per 100 Lb. Liveweight, Daily
Dairy cows, dairy heifers, beef cows, feeder steers, and stock cattle	3 lb.
Beef cattle on full feed	1–2 lb.
Sheep	1–1½ lb.
Horses and mules	1 lb.

201. Location of the Silo.—After the diameter and height of the silo have been decided on, the next concern should probably be the location. If the silage is all fed in one barn, the silo may be placed at the end of the feeding alley. If it is to be hauled to different points, provision must be made for backing a wagon under the chute. Figure 153 shows a plan for such a setup. Note the double doors allowing a wagon to be backed between silos for loading.

Other factors that must be considered in locating the silo are the need for room at filling time, the kind of power used, the length of tractor drive belt, and the space required for teams and wagons.

202. Silo Foundations and Walls.—The foundation for the silo must be made the proper size and be of good materials, because the weight that it must carry is very great. The fact that the silo is high in relation to its width makes it imperative

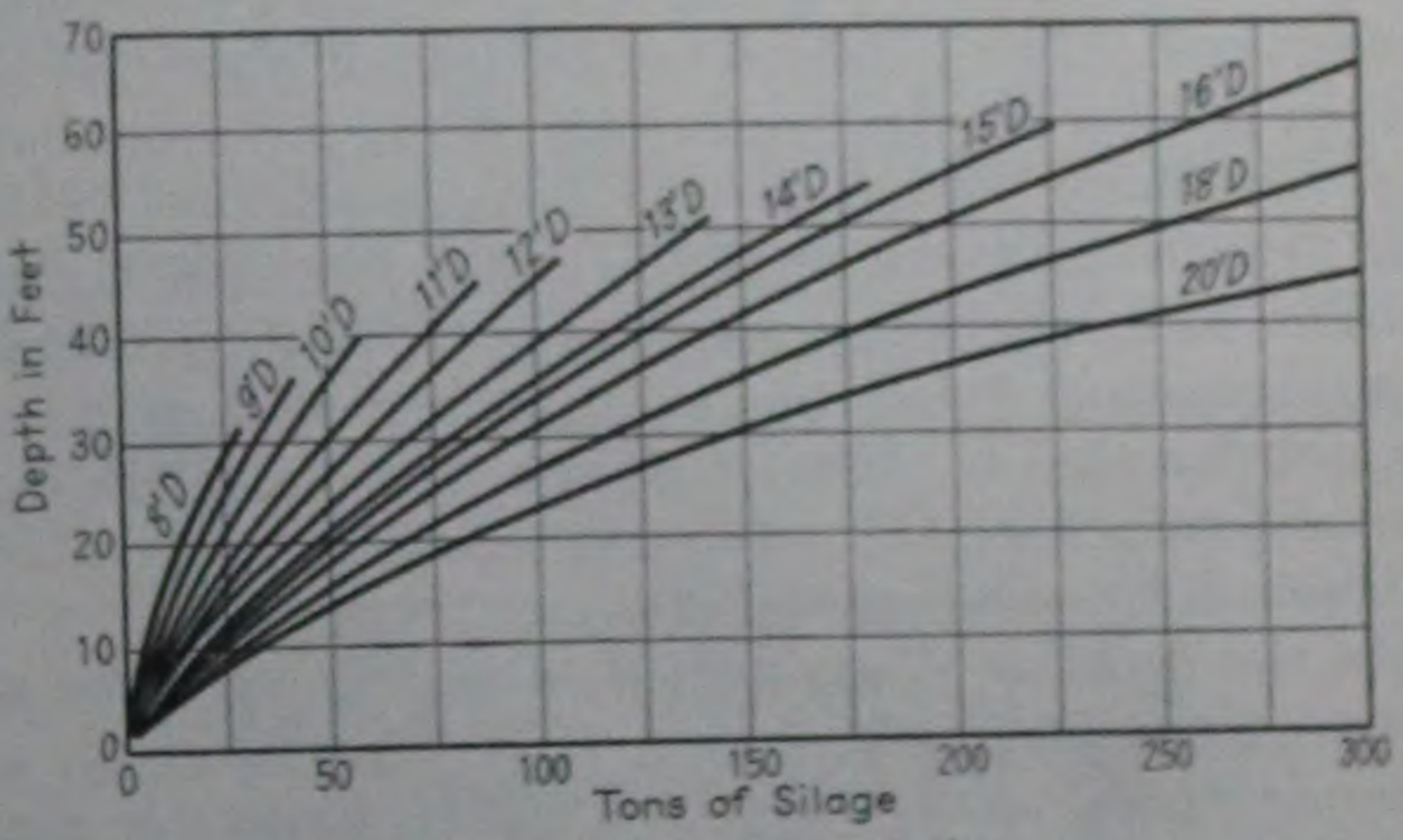


FIG. 152.—Capacity of silos.

that uneven settling of the foundation be prevented. The silo foundation must always be laid below the frost line and should always be deep enough to have good subsoil to serve as a base. The footing should be large enough so that the safe bearing

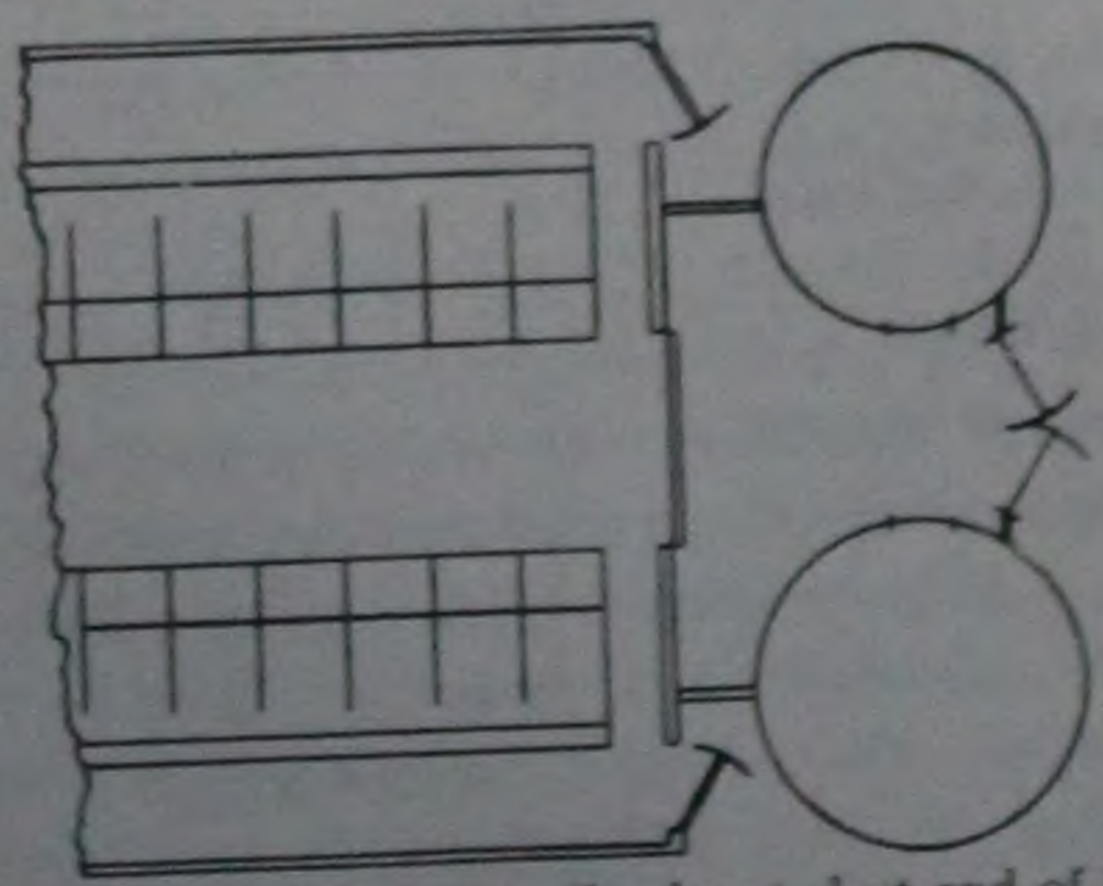


FIG. 153.—Plan showing silos located at end of barn.

power of the soil will not be exceeded. High-quality concrete probably makes the best foundation, although cobblestone of a good quality can be used satisfactorily.

Figure 154 shows the wall of a pit that is undercut to provide room for a 20-in. footing. A drain for the silo floor is desirable but not always necessary. A drain and a concrete floor are necessary only when the silo is located in wet, seepy land. A concrete floor may be found advantageous even if the silo is located on well-drained land, since it will reduce the work of keeping the silo clean.

Certain conditions must be met in the construction of any vertical silo. First, the walls should be plumb. Any marked deviation from this standard is sure to result in spoiled silage because of air's finding its way along the inside walls of the silo. The second requirement is that the walls be smooth in order to prevent friction and uneven settling that would also admit air and result in spoiled silage. Third, the walls must be strong enough to withstand the lateral pressure produced by the silage. Numerous tests have shown this pressure for corn silage to be about 11 lb. per square foot per foot of depth of silage. If silage is 30 ft. deep, the pressure on 1 sq. ft. at the bottom would be equal to 11 lb. $\times$ 29½ (the average depth of silage affecting this area) or 324½ lb. This pressure is exerted outward in all directions, subjecting the wall to a tensile stress. The amount of this tensile stress at any point may be computed from the following formula:

$$T = \frac{P \times D}{2} \tag{43}$$

where T = tensile stress in pounds.
P = the pressure per square foot.
D = the diameter of the silo in feet.

Grass silage produces about two times as much pressure as corn silage. By substituting 22 lb. for 11 lb. for corn silage, the pressure produced can be obtained where grass silage is used.[1]

203. Types of Silos.—*The wood-stave silo* is one of the first types of silo used and has been found quite satisfactory. One of the principal objections to this type is that it requires considerable attention in the summer, when it is empty, and also in the fall, after filling. As the silo dries out the hoops must be shortened, and after it is filled in the fall they must be loosened

[1] McCalmont, J. R., and H. E. Besley, *Agr. Eng. J.*, Vol. 20, No. 6, p. 227, June, 1939.

to prevent their cutting into and spoiling the staves. Wood-stave silos must be anchored to the foundation when grass silage is stored, for grass silage exerts a lifting pressure when part of the silage has been removed. This upward pressure is not great enough to cause trouble with corn silage.

Clay Block.—If an individual has used silage and knows that he will continue to use it in the future, the clay-block silo is a good one to build. The first cost is slightly higher than for most other types of silos, but the annual cost is not much different

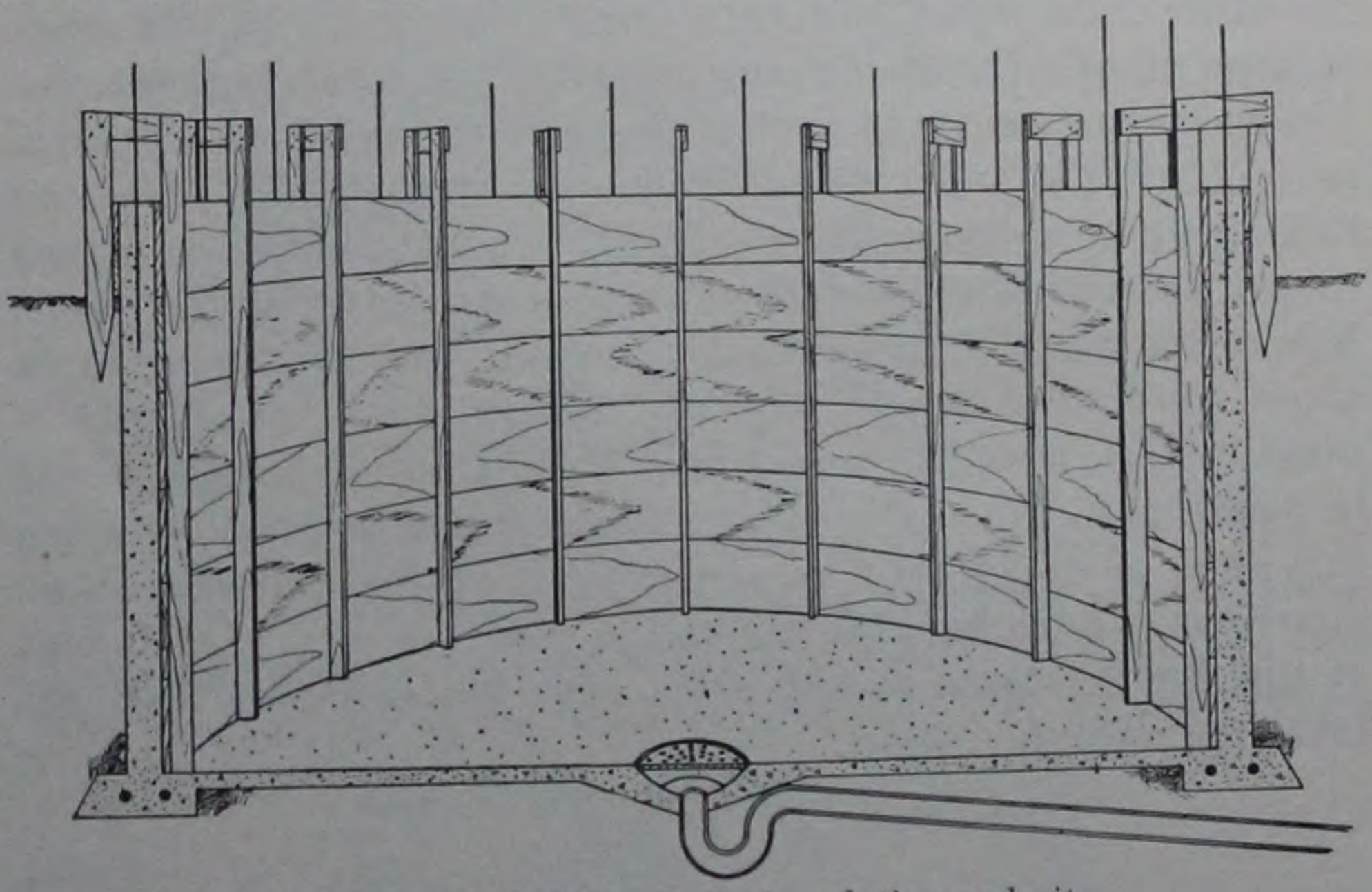


FIG. 154.—Combined silo foundation and pit.

from that of the wood-stave type (see Table 47). Blocks must be carefully tested before they are placed, for they are somewhat difficult to replace. Good mortar, properly cured, is essential if the joints are to remain air- and watertight. The beauty of the clay-block silo, its permanence, its fire-resistant qualities, together with its efficiency in preserving silage, make it a popular type of silo. It is sometimes criticized, because unless this same material is used in other structures, the clay-block silo does not tend to give unity to the building group.

Concrete Stave.—This type of silo has been used quite extensively in recent years. It is one of the less expensive permanent types. It can be constructed quickly and has been found to be quite satisfactory in keeping silage. It allows a little deeper freezing of silage but also allows quick penetration of the sun's

heat, resulting in more rapid thawing. Its permanence, fire-resistant qualities, and comparatively low cost account for its popularity.

Concrete Block.—Some farmers who have a supply of gravel on their farms have made silo blocks as time permitted and have then built up a silo at very low cost. Blocks may be cast to admit the steel in the mortar joints, or, in some instances, the

TABLE 47.—FIRST AND ANNUAL COST OF DIFFERENT SIZES AND TYPES OF SILOS

Diameter and height, feet	Cost per ton	Wood stave	Clay block	Concrete stave	Concrete block	Concrete
10 by 30	First	$6.75	$8.60	$7.53	$5.62	$4.25
	Annual	0.51	0.55	0.44	0.36	0.27
12 by 32	First	4.57	7.06	5.52	5.30	4.67
	Annual	0.35	0.49	0.36	0.34	0.28
14 by 36	First	3.95	5.30	5.00	5.00	3.68
	Annual	0.30	0.34	0.33	0.34	0.24
16 by 40	First	2.52	4.40	2.94	3.82	4.04
	Annual	0.20	0.31	0.18	0.28	0.28
18 by 45	First	2.42	3.85		3.14	
	Annual	0.19	0.32		0.23	
20 by 50	First		3.18			
	Annual		0.26			

reinforcement is placed outside the blocks. If these blocks are made so as to pass the absorption test such a structure should be quite satisfactory.

Monolithic Concrete.—This type of silo is used a great deal in areas in which materials for concrete are plentiful and not too costly. Where a good quality of clean materials is used with the proper observance of the water-cement ratio, together with adequate reinforcement, proper placing and curing of concrete, this type of silo has been found quite satisfactory.

The Wood-hoop Silo.—The first step in the building of this silo is the construction of the hoops. These may be formed by fastening a number of blocks on the circumference of a circle

whose diameter is equal to the diameter of the silo desired. Weatherboarding is assembled around these blocks, the thick side up on one board and the thin side up on the next, until a thickness of from 4 to 6 in. has been obtained. The individual pieces in each hoop are nailed and bolted together in this circular form. Glue may be used if desired. These hoops are usually placed 2½ ft. apart and held in place temporarily by scaffolding on the outside. Starting at one side of the desired opening, the inside is covered with 1- by 4-in. tongue-and-groove flooring. When the inside has been covered the scaffolding may be removed and the outside covered in a similar manner. Door openings are made between hoops, the ends lapping at the center of each hoop. If outside covering is not applied, an application of tar to each of the hoops will tend to prevent the absorption of water and consequent decay. Cost figures on this type are not available, but will be slightly less than for the wood-stave type.

The Snow-fence or Sisal Craft Paper Silo.—In some sections of the country the snow-fence or sisal craft paper silo has been used quite extensively (see Fig. 155). In many cases the silage is fed out during the fall and winter seasons. This prevents a good deal of loss that would occur in this type of silo if the silage were held over until late spring. Many farmers have used this type of silo as a supplement to a permanent silo that was too small to meet their needs; and in many cases it has been used to take care of corn damaged by frost or hot winds. This silo is made from so-called "snow fence" (4-ft. lath woven together with four sets of connecting wires). A suitable length of fence is cut to make the diameter desired. This is spliced carefully and set up in the form of a cylinder 4 ft. high, of such diameter as is needed. Specially treated paper is placed inside the fencing and this space filled with silage. A second circle of fencing is then set in place above the first. The lower edge of the second row is placed inside the first row of fencing and outside the first row of paper lining. Paper is then put in place, allowing a 6-in. lap. The second cylinder of paper is placed inside the first to allow for settling without tearing paper. The final height should not be greater than the diameter, and the silo should be located on level ground to ensure even settling.

The *trench silo*, as the name indicates, consists simply of a trench dug in the ground. It may be filled with grass, cut corn,

or sometimes with corn bundles or other materials that are allowed to ensile (see Fig. 156). Thorough packing and plenty of moisture are essential for the success of the trench silo. The walls are usually dug to a slope of 1 to 4, because the earth does not cave in so badly with this slope as with vertical walls, and, also, the silage settles against the sides, eliminating air pockets. The silo trench must be located so as to drain well, and usually

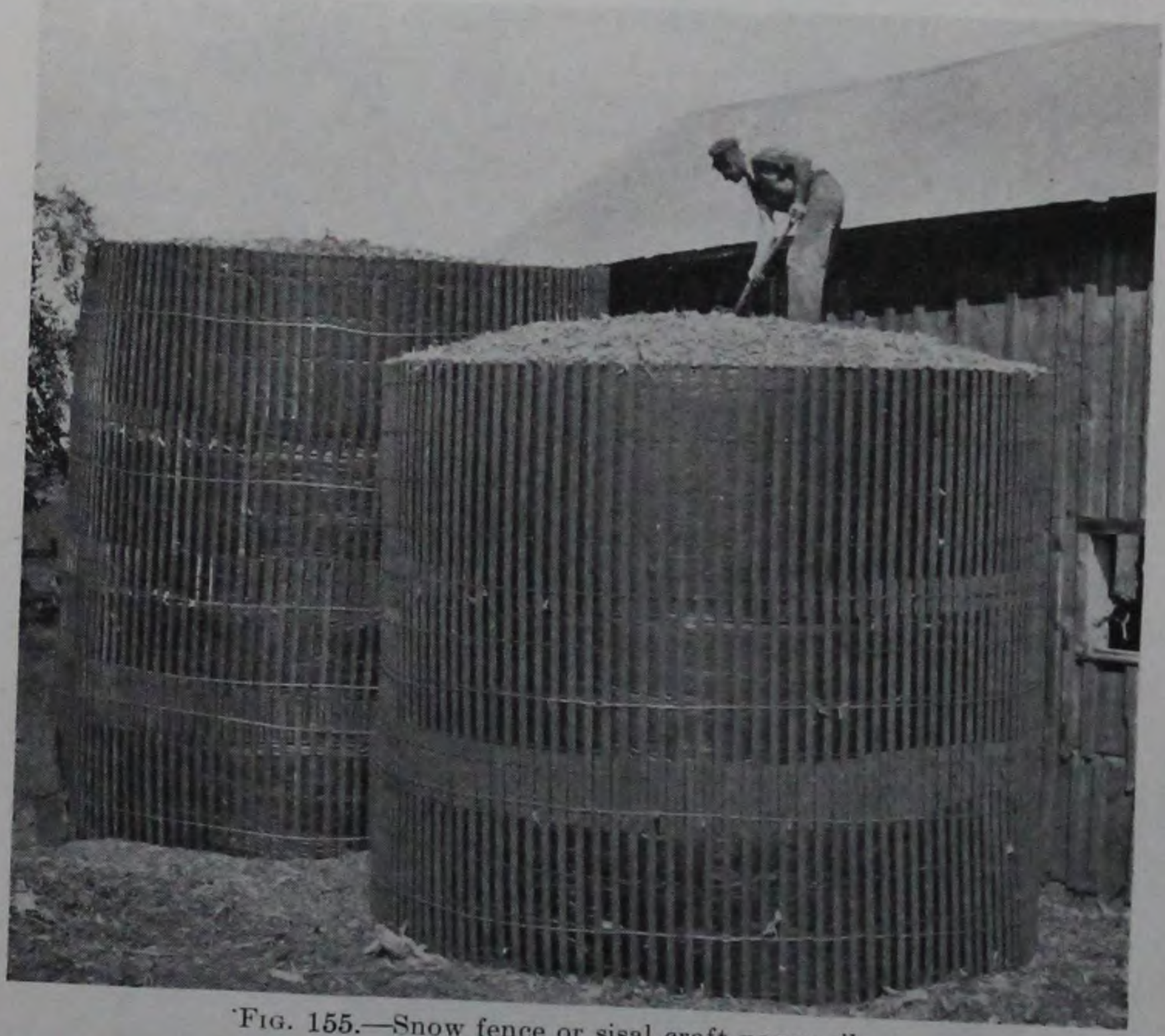


FIG. 155.—Snow fence or sisal craft paper silo.

the earth excavated is used to build up the sides to prevent surface water from entering.

The cross-sectional area is very important in preventing waste during the feeding season. If the silage is removed by means of a wagon, the bottom width will need to be 6 ft. so that the wagon can be backed in for loading. If a silage cart or carrier is used, the bottom width can be narrower. The silage is fed from the end rather than from the top, and most farmers are agreed that it is necessary to feed off about 2 in. per day to keep the silage

fresh during the winter feeding period and about twice this amount during the summer months. The silage in the trench silo is not subjected to pressures so great as in the vertical silo, and it is therefore necessary to remove a greater amount per day in the trench type in order to ensure fresh silage. Table 48

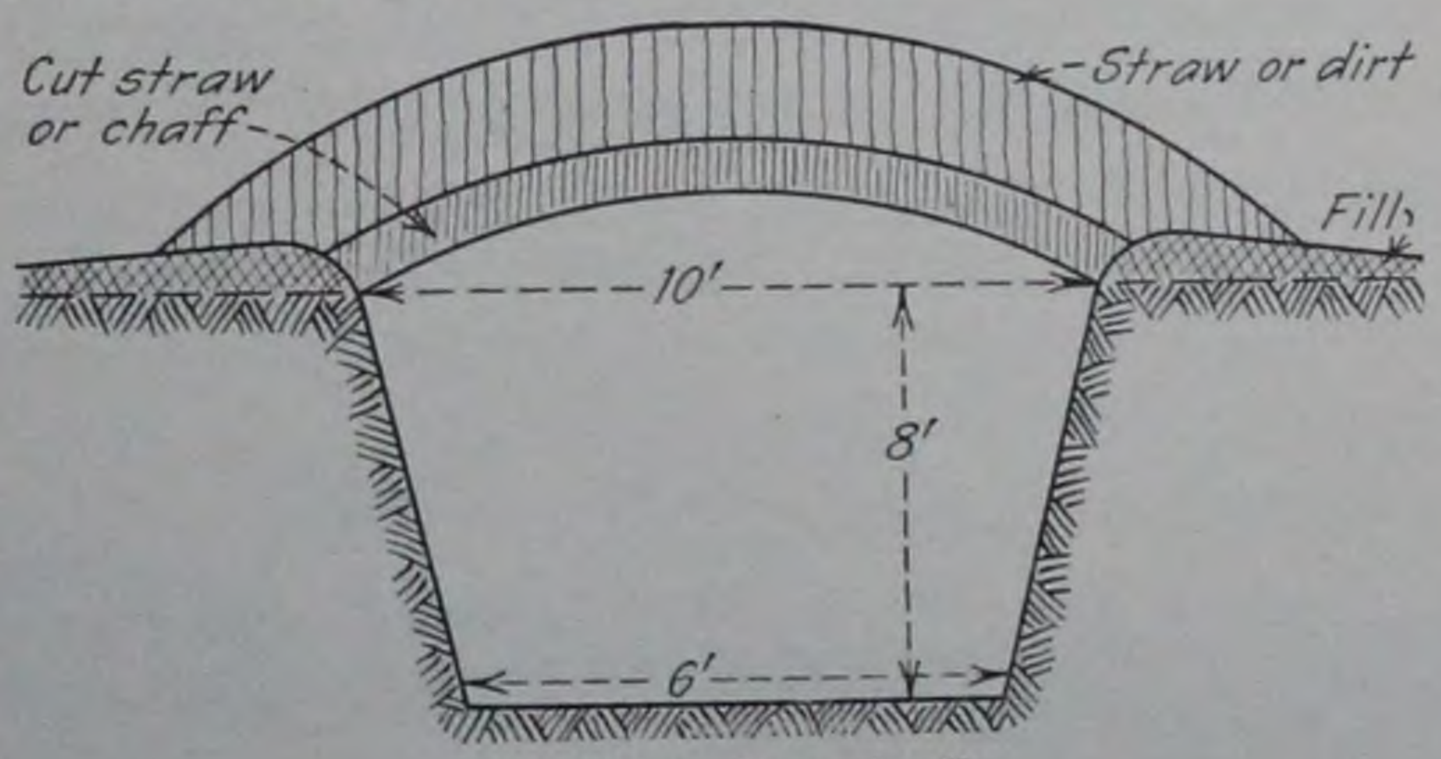


FIG. 156.—Trench silo.

gives the amount of silage that should be fed daily from trench silos of different sizes.

The size of trench silo can be increased as desired if it is remembered that the depth should be kept at some point near the average width. The length will be determined by the length of the feeding period.

TABLE 48.—NUMBER OF POUNDS THAT MUST BE FED DAILY FROM DIFFERENT SIZES OF TRENCH SILOS

Pounds to be fed daily	Bottom width, feet	Top width, feet	Depth of cut, feet
270	6	9½	7
318	6	10	8
360	7	11	8
460	8	12½	9
525	8	13	10

It is often necessary to know the first cost of silos and the cost per year of owning them. The data in Table 47 give information on annual costs of different sizes and types of silos.[1]

Questions and Problems

152. A farmer has had temporary silos for a number of years and now desires to build a 100-ton permanent silo on his farm. What type would you recommend? Why? What would it cost him?

[1] *Ibid.*

153. Another farmer has never fed silage but feels that he could use it successfully. What type of silo would you recommend for him? Give reasons for your choice.

154. A farmer owns a 90-ton silo. He would like to know what the corn would be worth that would be required to fill the silo if he were to leave the corn in the field and harvest it in the fall. The corn will make about 40 bu. per acre. Corn is worth 60 cts. per bushel and will cost him 5 cts. per bushel to harvest. It will make 8 tons of silage per acre. He would like to know what his immediate cash outlay would be if he filled the silo. He thinks that the silage will be worth $7 per ton to him for feed. Which would make him more money? How much?

155. A dairyman has a herd of 36 cows and the usual complement of young stock. What size silo would you recommend for him for a 160-day winter feeding period? For a 90-day summer feeding period? What size trench silo would he need for the winter feeding period?

156. In a silo 20 ft. in diameter and 40 ft. high, the reinforcing bars are placed 1 ft. apart in the mortar joints. What size steel rod should be used in the first joint above the foundation when corn is used for silage? When grass is used for silage?

CHAPTER XXXV

APPLE AND POTATO STORAGE

204. Apple-storage Structures.—The problem of desirable apple storage involves proper regulation of temperature, humidity, and air circulation. It is necessary to maintain temperatures low enough to retard ripening of the fruit and to check the development of fungi and high enough to prevent freezing. This may be done by admitting air into the storage room when

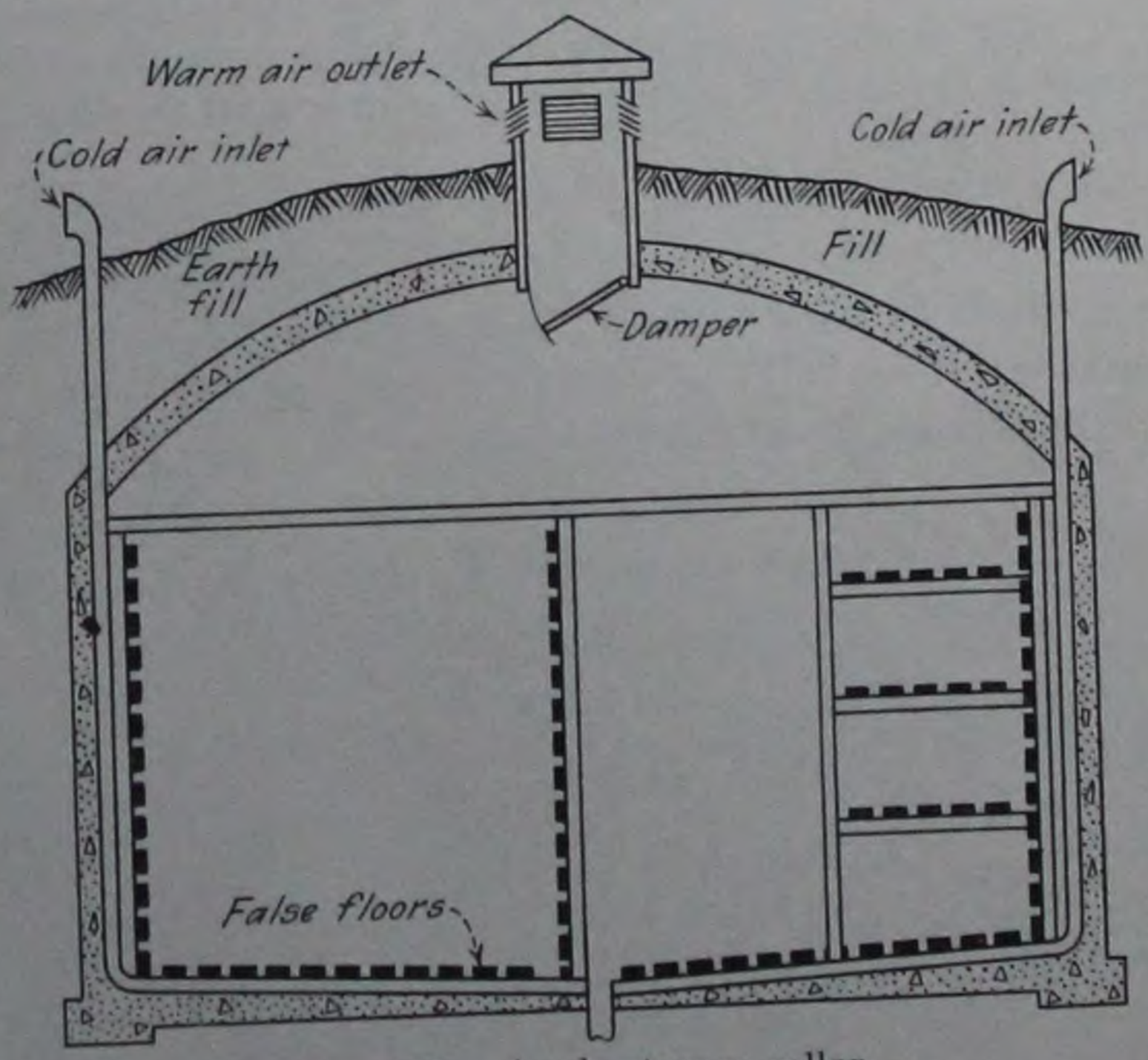


FIG. 157.—Apple-storage cellar.

outside temperatures most nearly approach those needed inside the building and preventing air change when outside temperatures are above or below the range desired. Humidity must be regulated to keep the air of the storage building moist enough to check wilting or shriveling of the fruit, yet dry enough to retard the growth of molds and fungi. This is accomplished by ventilation or by evaporating water in the room in case the air is too dry. Gases resulting from the ripening process of perishable

products may accumulate in excess quantities in parts of a storage room unless the air of the room is circulated or removed through ventilation. Successful storage of apples requires a proper balance of temperature, humidity, and air circulation.

An ordinary cellar may be frost-proof and still be wholly unsuited to apple storage, because it does not provide sufficient air change to cool the fruit, to regulate humidity, or to remove deleterious gases given off by the fruit (see Fig. 157).

Temperature.—When outdoor-air temperatures are lower than those in the storage room or of the fruit, and not too low for safety, the ventilation system should be opened so that cold air will be drawn in. When outside temperatures are above those inside, the ventilation system should be closed to prevent the warmer air from entering. If ventilators are open on a warm day and the wind is blowing, some air change will occur, even though the air is heavier inside the building. By opening the ventilation system at night and closing it in the day a temperature equal to the mean for the 24-hr. period may usually be obtained.

TABLE 49.—AMOUNT OF AIR THAT MUST BE CIRCULATED TO COOL APPLES

Mean Difference between Storage and Outside Temperatures, °F.	Cubic Feet of Air to Cool 1 Bu. Apples 1°F.
3	73
4	55
5	46
6	40
7	36
8	34
9	33
10	32

If the walls and roof are insulated by a covering of earth or by some other means, there will be no difficulty in maintaining the proper inside temperature in winter months.

Before designing a ventilation system for a storage building, it is necessary to know the amount of air required to cool the stored products to the desired temperature. Table 49 gives information on this subject.

Under a majority of conditions a temperature difference of 5° may be used in figuring the size of flues for the ventilation system.

Humidity.—When the air of a storage room is too dry, the apples lose moisture and wilt or shrivel. On the other hand, if

the air is too humid, there may be condensation on the fruit and on the containers, walls, ceilings, etc., resulting in the growth of molds. This seldom presents a problem in common storage if the temperatures are near the freezing point. The wilting or shriveling of products, however, is probably the most serious problem with which the owner of air-cooled storage must contend. The humidity usually is automatically taken care of during the fall months, when the room is opened frequently and therefore well ventilated. A storage humidity similar to the average humidity of the outdoor air in the fall season in the Middle West is easily maintained and is satisfactory to prevent wilting and the growth of mold. One or the other of these storage troubles, however, frequently exists during the winter months. For apples, a relative humidity of about 85 per cent is necessary to prevent wilting of varieties like Baldwin, Jonathan, Russets, Golden Delicious, and Spitzenberg, when stored in open containers.[1]

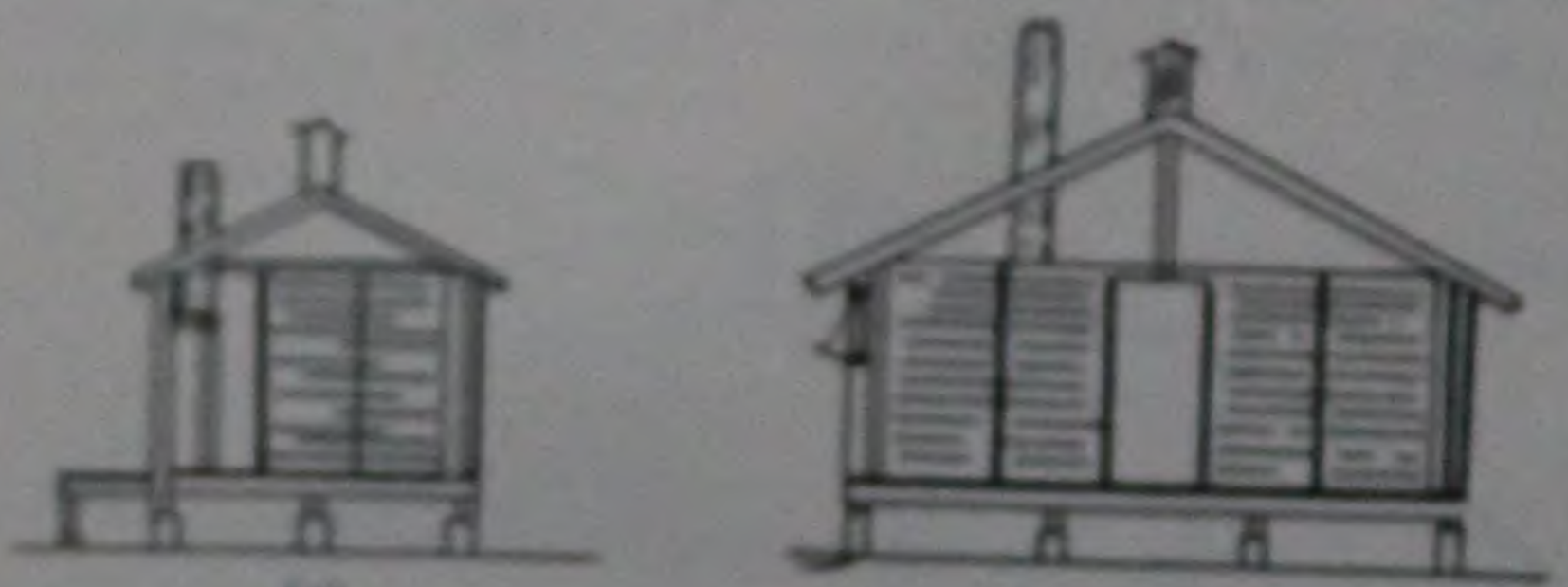
Humidity can be regulated to some extent by use of clay floors, by frequent sprinkling of concrete floors, or by the use of water containers placed about to allow evaporation of water. Water tanks submerged under the floors may be used. Air intakes are often introduced over such tanks. The air inlets sometimes consist of a tile line laid for some length through the soil. This line, in addition to furnishing fresh air, may be the drain for the storage room.

205. Sweet-potato Storage.—The storage of sweet potatoes is a sound economic practice that makes the product available for a large part of the year and in many cases obviates the necessity of selling the crop as soon as it is harvested, when prices are often low. At one time this was a real problem, and the development of storage methods and structures was of great value to the sweet-potato industry. The capacity of sweet-potato-storage structures in this country is something over 12 million bu., a quantity sufficient to have a stabilizing effect on the industry and to make this vegetable available when it cannot be supplied directly from the field.[2]

[1] MARSHALL, ROY E., The Construction and Management of Air-cooled Storages with Special Reference to Apples, *Mich. State Coll. Agr. Expt. Sta. Bull.* 143, May, 1932.

[2] THOMPSON, H. C., Storage of Sweet Potatoes, *U.S. Dept. Agr., Farmers' Bull.* 1442.

To keep sweet potatoes in good condition, they must be well matured before they are dug, carefully handled, well dried or cured after being put in storage, and kept at a uniform temperature after they are cured. While the newly dug sweet potatoes are being brought in, a fire should be kept in the storage house to ensure its being dry. A temperature of from 80 to 85°F. with plenty of ventilation should be maintained for 10 days or 2 weeks, depending on weather conditions and the variety of potatoes. Ventilation is absolutely necessary, and even if it is not possible to keep the temperature up to 80°, it is necessary to leave doors, windows, and ventilators open so as to drive out the moisture-laden air. Doors and windows may be closed at night and on



(a) (b)

FIG. 158.—Sweet-potato storage houses: (a) house 12 by 16 ft., designed to hold 400 to 500 bu. in crates; (b) house 24 by 60 ft., designed to hold 4,000 bu. in crates.

cloudy days. When potatoes are thoroughly dried or cured, the temperature should be gradually reduced to 55° and kept as near that point as possible during the remainder of the storage period. If the temperature goes below 48°, a fire should be made and the temperature raised to 55°.

Most of the successful storage houses are made of wood using a double wall to conserve heat and prevent condensation of moisture. Figure 158 shows two sweet-potato houses of different sizes.

208. Storage Structures for White Potatoes.—Several factors influencing the effectiveness of storage must be considered in the design of white-potato-storage structures. These factors are temperature, light, humidity, aeration, and size of bin or pile. William Stuart, horticulturist of the U.S. Department of Agriculture, reports as follows on the question of temperature:[1]

[1] STUART, WILLIAM, Potato Storage and Storage Houses, *U.S. Dept. Agr., Farmers' Bull.* 847.

Our present belief, based upon the last four years' experience with an artificially refrigerated potato storage room, is that a temperature of 36 degrees F. is sufficiently low for all practical purposes, and that in the earlier portion of the storage season a temperature of 40 degrees is probably just as satisfactory except where powdery dry-rot infection occurs.

Potatoes, when exposed to strong or even modified light, are soon materially injured for food purposes. It is necessary, therefore, to exclude all light from the storage house. Wherever it is feasible, the storage house should be lighted by electricity. Little information is available relative to the proper humidity for storage. One investigator[1] suggests that from 85 to 90 per cent at 36°F. is a desirable relative humidity. It must be high

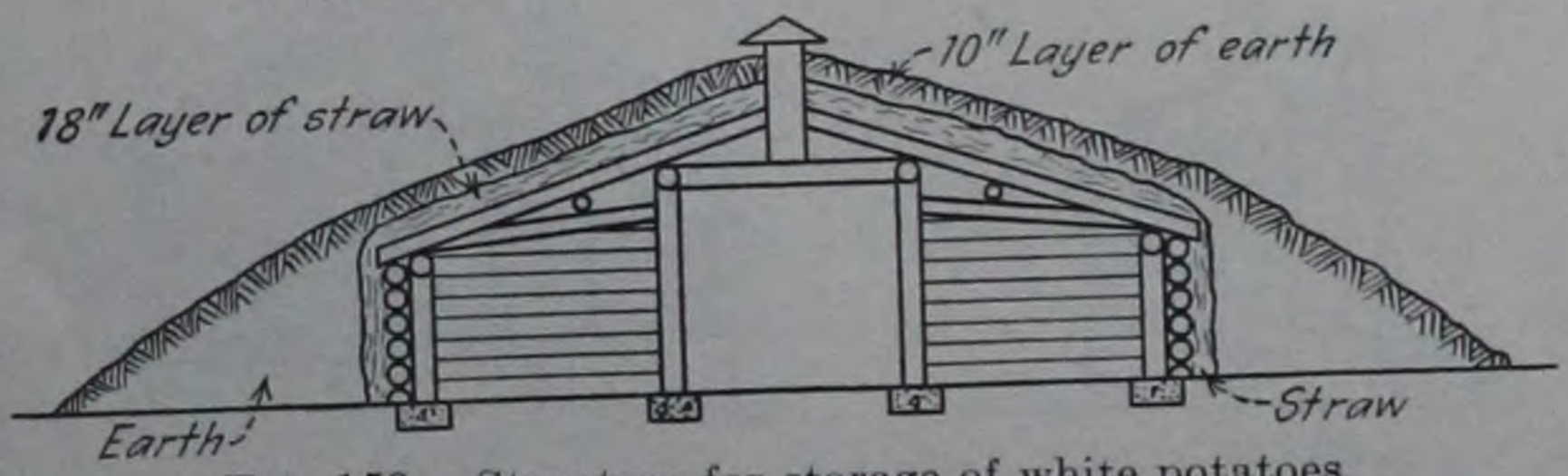


FIG. 159.—Structure for storage of white potatoes.

enough to prevent wilting and low enough to prevent condensation of moisture on the tubers.

Ventilation.—In order to ensure an ample supply of pure air in the storage house, it is necessary to make generous provision for ventilation. The ventilators or air flues should be so arranged as to ensure a rapid and even distribution of air throughout the structure (see Fig. 159).

Size of Bins.—The size of piles or bins that can be used will depend on the maturity of the potatoes when stored. Where a subfloor with free circulation under it is used and ventilated partitions placed from 5 to 6 ft. apart, the potatoes may be piled to a depth of 10 ft. or more. The air-cooled cellar shown in Fig. 157 may be used satisfactorily for potatoes. Ventilator regulation would be much the same as for apples, drawing in air when outside temperatures are low and closing ventilators when air is warm, etc.

[1] COOPER, MADISON, "Practical Cold Storage," 2d ed., p. 503, Nickerson & Collins Company, Chicago, 1914.

Questions and Problems

157. What would be the best indication of need for ventilation in an apple-storage house? If the temperature was the same outside as inside, what should be done? If days are warm and nights are cold, what procedure should be followed?

158. An underground storage building holds 2,000 bu. of apples stored at a temperature of 45°F. If the Rutherford system of ventilation is used, what size and height of stack should be built?

159. What are the conditions needed for storing sweet potatoes at the time of harvest? During storage?

160. What are the conditions needed for storing white potatoes? In what way do these conditions differ from those needed for storage of apples?

PART VII

The Farm Home

CHAPTER XXXVI

PLANNING THE FARM HOME

At one time in our history farmhouses were more convenient, comfortable, and healthful than city houses. This was during the period immediately preceding the development of modern water and sewage-disposal systems. As industries grew, city residential sections became more congested; houses were crowded together, and it was no longer possible for sunlight and fresh air alone to take care of the problems of sanitation that arose. Families were not able to find satisfactory individual water supplies. Epidemics resulting from contaminated drinking water and generally unsanitary conditions broke out in these crowded city areas. The fact that the problem was urgent and that it was concentrated made cooperative action possible. Through this cooperative action the people in the cities now have sanitary water supply, sewage-disposal systems, light and gas service available by simply paying their share of the cost of the service. The farmer, because of his isolated position, must be his own utility engineer. He must buy, install, and operate his own sewage-disposal, water, and heating systems. For this and other reasons, the farm home has lagged far behind the city dwelling in modernization. Many farm homes today are no more modern than were those of the pioneer period. In these homes water is still carried into the house from the well or spring, wastes are carried out, and other chore operations are done just as they were in early days. The housing survey made by the Federal government in 1934[1] shows the extent of this lag in

[1] The Farm-housing Survey, directed by the Bureau of Home Economics in cooperation with Bureau of Agricultural Engineering Extension Service and Office of the Secretary, *U.S. Dept. Agr., Misc. Pub.* 323, March. 1939.

development. Only 17.8 per cent of the farm homes in America in 1934 had electricity; 8.5 per cent had flush toilets; 11.2 per cent bathtubs; 4.5 per cent had septic tanks; and 28.4 per cent had kitchens with sink and drain. This leaves 71.6 per cent of the farm homes developed but little beyond the pioneer stage. Within the past few years, however, there has been a noticeable increase in appreciation of the farm as a place to live, and consequently additional attention has been given to ways and means for its improvement.

FACTORS TO BE CONSIDERED IN PLANNING THE FARM HOME

In planning the farm home there are three different phases to be considered in order to make the plan complete. The house must be *efficient* for the work to be done, *comfortable* for the persons who are to live in it, and *attractive* to both the farm family and the neighbor who passes by. Few, if any, plans will be ideal for all these objectives because of special conditions, such as financial limitations, equipment and materials to be used, environment, etc.; however, the degree of efficiency, comfort, and attractiveness secured will be greater for having given thought to each of these factors in making the plan.

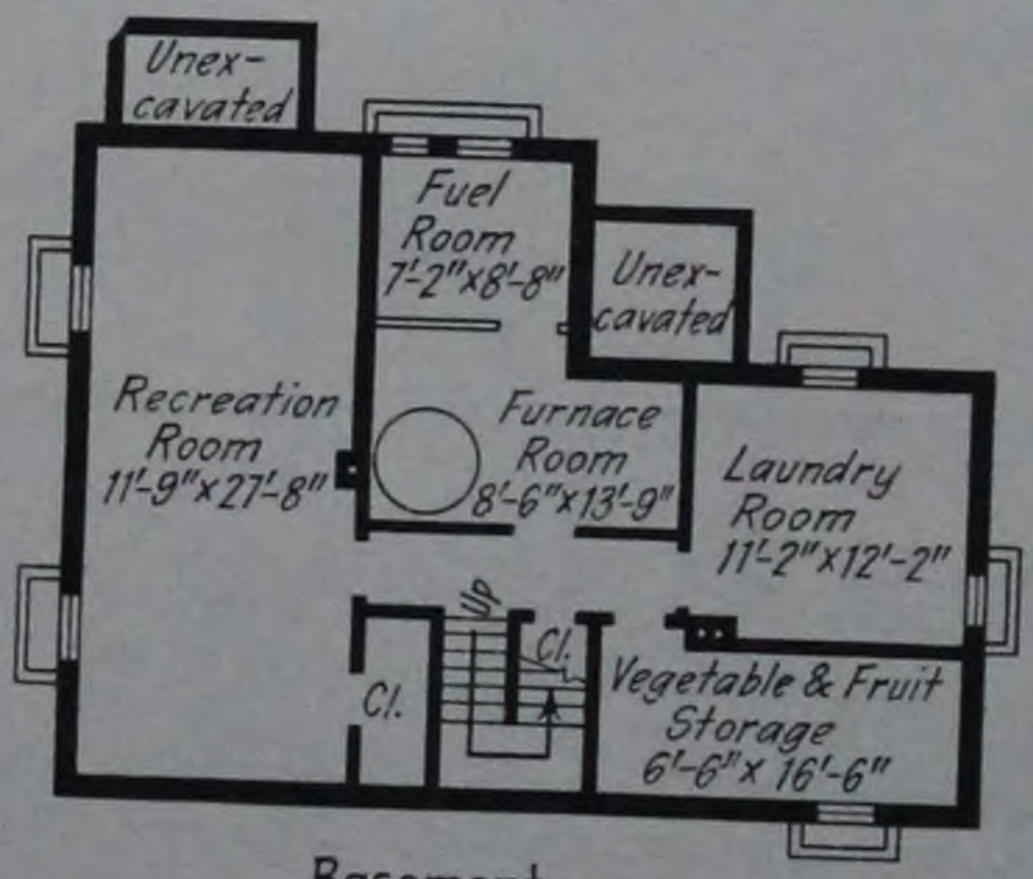
207. Efficiency in doing the work of the household can be increased by proper utilization of space and arrangement of equipment. To accomplish this end consideration must be given to the different kinds of work done, the frequency of their repetition, and the possibility of coordinated activity on several different tasks at the same time. The different tasks that the farm woman performs are like the miscellaneous articles at the farm sale, too numerous to mention. She must prepare, cook, and serve food, wash dishes, clean and dust, do laundry work, sew, fire the stove, and tend the garden in addition to many other duties.

The preparation, cooking, and serving of food requires in the average farm home about 25 hr. per week, 52 weeks per year. Few other farm enterprises require so much time and energy. In this work the refrigerator, the sink, work surfaces, the stove, and the serving table will be used in the order mentioned and should be arranged to enable work to be done with as little loss of time and energy as possible. The return of dishes after meals and the washing and storing of them for future use involves

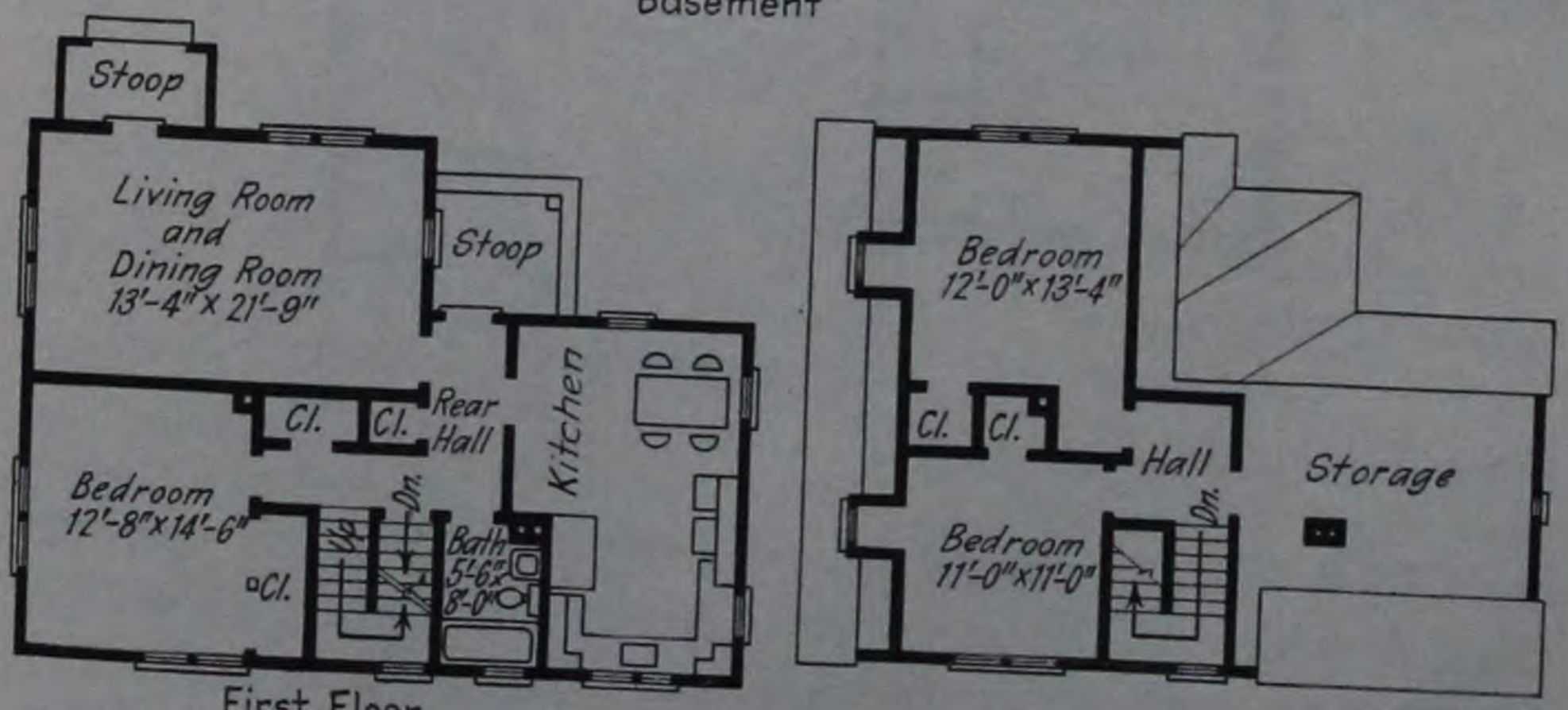
frequently repeated processes and offers opportunity for improving efficiency. In some homes a considerable saving in time and energy is accomplished by *serving a greater part of the meals in the kitchen*. The average farm home employs no kitchen help, and the labor saving made by serving meals in the kitchen is important to the farm woman. Then, too, the modern kitchen is a colorful, pleasant room, with its easily cleaned floors, walls, and equipment. Of course, the kitchen that is to be used also for family meals will need to be planned very differently from one that is used for preparation and storage of food only. The plan shown in Fig. 160 illustrates an arrangement of a kitchen planned as a place for serving meals as well as for preparing and storing food. This arrangement will no doubt be very convenient for everyday living. The regular dining room that is a part of the living room, not convenient to the kitchen, will be used so infrequently that it should be given a minor place in planning.

In the farm home there are other important tasks that occur weekly or seasonally. Washing, ironing, canning of fruit, vegetables, or meat, rendering lard, etc., must be fitted into the regular daily schedule of work. Recognizing this, many plans are now made to include a workroom. This room is placed adjacent to the kitchen so that both the special and the regular work can be done with the smallest loss of time and energy. The efficiency thus accomplished is made possible by planning after a thorough study has been made of the work to be done (see Fig. 161). Serving a part of the meals in the kitchen decreases the necessity for a dining room. There are times, however, when a fairly large dining room would be desirable, and by combining the dining and living rooms a sufficiently large dining space can be provided. This room can be set as a dining room when a large group of guests or laborers are to be served, or it can be arranged as a spacious living room for social gatherings, club meetings, etc.

A sufficient number of bedrooms in the home may logically be considered under the heading of efficiency. Three bedrooms constitute the minimum requirement for the average farm family, and the living room can be utilized for additional sleeping space when needed. This is mentioned under efficiency because the work of caring for beds and bedding is less where beds and bedding have their place and no moving is necessary. Bed



Basement



First Floor

Second Floor

FIG. 160.—A house that meets many of the requirements of the farm home. (Designed by H. E. Wichers, Architect-Editor of *Successful Farming*.)

making can be postponed without inconvenience until rush work is over.

Nothing will contribute more toward efficiency than the provision for adequate storage space. A closet 5 or 6 ft. wide

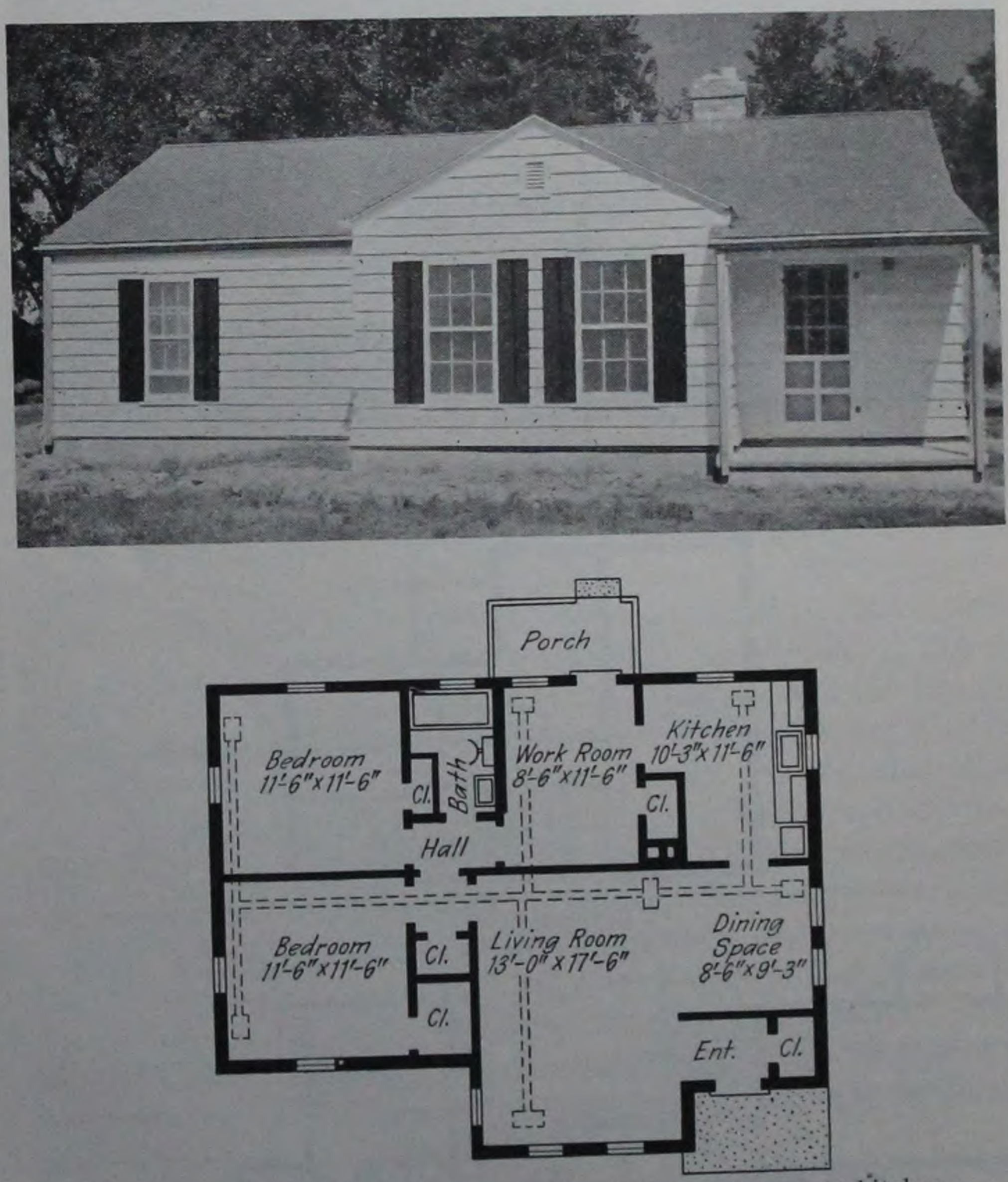


FIG. 161.—A low-cost farmhouse with workroom adjacent to kitchen.

and 2½ ft. deep, with sliding or hinged doors that will open up the full width of the closet, is a great convenience. Built-in drawer space for linens and towels in or adjacent to the bathroom, storage space in the workroom for equipment, supplies, and for work coats, etc., save time and result in an improvement in the

appearance of the house. Storage spaces in the kitchen for supplies, dishes, cooking utensils, and cleaning equipment are a necessity. Figure shows one plan for providing such storage space.

Adequate work surfaces must be provided in the kitchen. The sink furnishes a waterproof surface for washing vegetables, dishes, etc., and drainboards on one or both sides are convenient because of the additional working surface they provide. Another con-

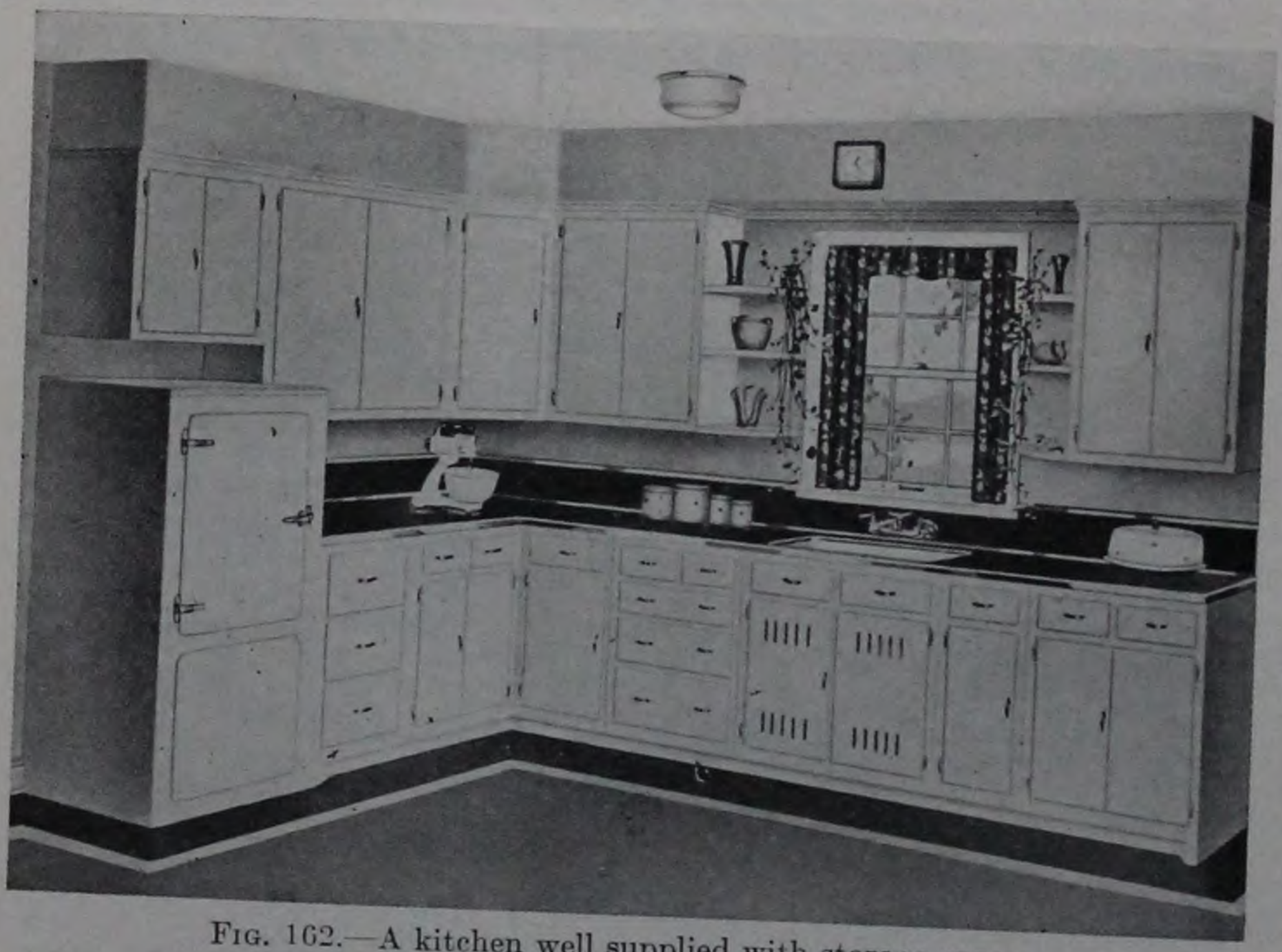


FIG. 162.—A kitchen well supplied with storage space.

venient work surface is supplied by the kitchen cabinet. Cooking surfaces and a serving table complete the essentials for this phase of planning. Work surfaces should be built at the right height so that the housewife may do her work comfortably. One requirement common to all these surfaces is that they be well lighted. Casement or regular windows over the sink serve two purposes. They furnish light for the work to be done and provide ventilation in hot weather. Artificial lights with reflectors to concentrate the light where needed are essential. The work surfaces must be arranged in relation to windows so that the light will reach them from one side or the other.

A fuel room in the basement or adjacent to the house, if no basement is included, reduces the number of steps to be taken in supplying fuel. A fruit and vegetable room separated from the remainder of the basement so that a temperature of from 36 to 50°F. and a relative humidity of 50 per cent can be maintained is necessary for satisfactory fruit and vegetable storage. A cellar under the house or a cave beside the house serves this purpose where there is no regular basement.

In many two-story houses the bathroom is located on the second floor. With such an arrangement a lavatory and stool

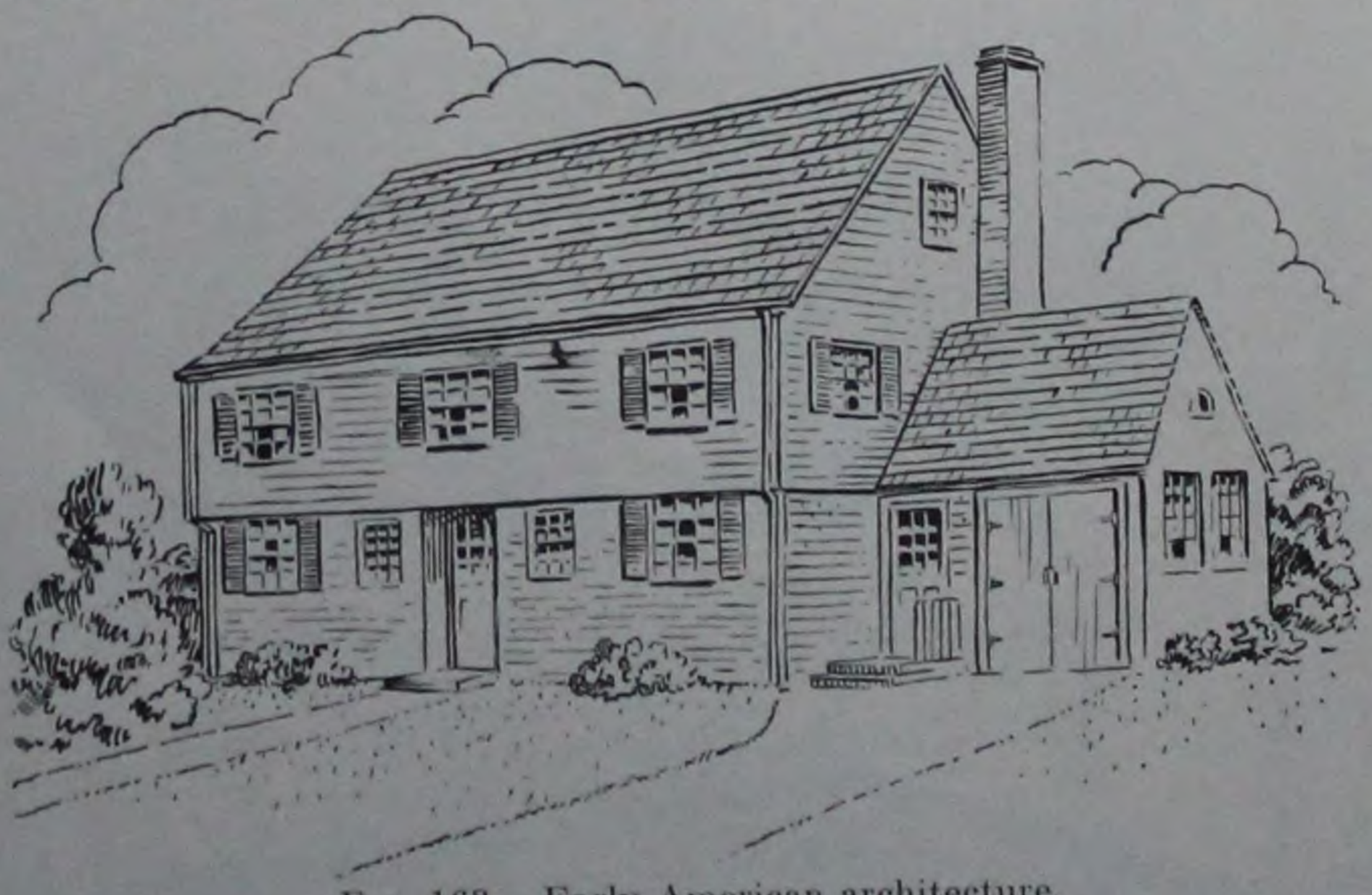


FIG. 163.—Early American architecture.

located on the first floor are desirable. When only one bathroom can be provided in a two-story house, it is usually more convenient and desirable for it to be located on the first floor. This location makes the work of installation less difficult as well as less expensive. One outside window for light and ventilation is essential in the bathroom.

A recreation or playroom is included in most modern plans. If this room is located close to the laundry it can be used as a drying room for clothes when needed. When the basement can be well lighted and ventilated, it is a desirable place for the recreation room. Walls and floors in the basement are not easily damaged, and noise is effectively controlled.

Labor-saving equipment is a very important factor in making the home efficient. There are few homes that do not have some

equipment purchased for the purpose of saving time and energy. The order in which such equipment is purchased is an indication of the importance of different items in the minds of the farm women of the country. In the survey previously referred to it was found that these items had been purchased in the following order: some type of stove other than the coal or wood range for cooking; pump, sink, and drain; ice box or refrigerator; electric lights; electric washer; electric iron; vacuum cleaner; central heating; and bathroom. If a farm woman who has all this equipment today were asked to discard these items one by one, she

FIG. 164.—New England colonial architecture.

would probably confirm the judgment that the farm women of the country have used in purchasing them. The rural-electrification program and the improvement of equipment are bringing about rapid developments in the efficiency of farm homes. Water under pressure is kept available by electric-powered systems that require little or no attention. Modern heating systems maintain any desired temperature by the setting of an electrically controlled thermostat. Electric washing machines clean the clothes ready to hang on the line. Electric dish washers, with a limited amount of supervision, probably do a more thorough job of washing dishes than could be done by hand. Power mixers, rotary ironers, and automatically controlled kitchen ranges are no longer dreams but are now in use in many

homes. Such equipment is enabling the farm women of our country to give more time to their families and still have time to take their place in outside activities.

208. Comfort in the farm home is one of the very important requirements, because it has a bearing on the general well-being of the whole farm family. Comfort in the home, as in other buildings on the farm, is dependent on temperature, humidity, and air movement. A comfortable temperature for different parts of the house varies from 78° in bathrooms and 76° in the

FIG. 165.—Dutch colonial architecture.

living room to 68° in the laundry and the recreation room. Heating units that can be regulated closely add proportionately to the degree of comfort. The ability to control temperature depends on the kind of fuel used, the design of the furnace, the amount of heat loss through walls, ceilings, etc., and the amount of air change provided. Usually no special construction is made for ventilation unless it be the fireplace. Frequent opening of doors and the opening of windows as needed make sufficient air change possible. Air circulation is not needed so much in cold weather as it is in summer, when the relative humidity and the temperature are high. In winter the absolute humidity is low, and it is often necessary to add moisture to the air. Fifty

per cent relative humidity is desirable for comfort, but this amount of humidity causes condensation on windows, ceilings, and walls in cold weather unless adequate insulation is provided. Forty per cent is a safer standard for ordinary houses. If both outside temperature and relative humidity are high, some improvement in inside temperatures can be secured by opening windows at night and keeping them closed throughout the day. Wide projecting roofs and window shutters are helpful in keeping heat out of the house. Electric fans or air-circulating furnaces improve the conditions for comfort by increasing evaporation rates from the body.

Air-conditioning systems may improve the foregoing conditions by lowering the temperature, leaving the absolute humidity the same; or they may lower both the temperature and the humidity. When refrigeration is used to cool the air or to cool and dry it, as the case may be, there must be a limit established if healthful conditions are maintained. From 10 to 15° difference between inside and outside temperatures has been found to be the greatest difference that is satisfactory for buildings where people are going in and out. Some factories maintain a lower temperature where workers stay in the building throughout the day. When economical methods are developed for drying the air, this will probably be the more satisfactory method to use in establishing a comfortable environment.

Temperatures may be high and relative humidity low, as in the southwestern part of the United States. Under these conditions the evaporation of moisture from curtains or window coverings provided for the purpose may maintain comfortable conditions. The relative humidity will be increased, but it will still be sufficiently low for comfort. This recalls the statement in an earlier chapter that to secure comfort an environment that will enable the control of body temperatures by physical means must be maintained.

As has been stated, it is usually necessary to give some attention to insulation if comfortable conditions are to be maintained. The amount of insulation needed depends on the lowest sustained temperature for the area involved. The temperature zones are based on this factor, and therefore more or less definite recommendations in regard to insulation can be made for each zone. Zone 1 requires very thorough insulation of walls, ceilings, and

foundations and the use of carefully installed weatherstrips, storm doors, and windows. Zone 2 requires insulation of ceilings and walls and the use of window and door strips. Storm windows are recommended as a good investment. Zones 3 and 4 require insulation in ceilings for both winter and summer protection. (The term *insulation*, as used in this discussion, refers to additional material added to the regularly constructed wall for the purpose of reducing the heat conductivity of walls.)

FIG. 166.—Eastern colonial architecture.

209. Attractiveness.—The appearance from within as well as from without should be given consideration in the plan. Views made possible in planning the farmstead should be framed by the living-room windows. Such windows may extend to the floor if the immediate view warrants or if the slope of the land places the interesting outlook below the view of persons seated in the living room. Rectangular rooms with the width approximately three-fourths the length are desirable for easy arrangement of furniture and equipment. Symmetrical placing of windows and doors makes for pleasing appearance. The fireplace contributes some heat and provides ventilation as well as furnishing an interesting center for the living room. It adds much to the attractiveness of the home and should be provided whenever

possible. Uniformity in trim, arched openings, wall coverings, etc., lend unity and contribute much to the interior attractiveness of the home.

The outside appearance is worthy of consideration, since it is the thing by which others judge the home. Many people are eager to show individuality in the home, but it is much more effective to utilize one of the recognized types of architecture. Colonial architecture, with its modifications for different parts of the country, is always a suitable choice for the farm home.

FIG. 167.—Southern colonial architecture, characterized by the massive columns, along with other colonial features.

The different types of architecture shown in Figs. 163 to 169 have been developed through the years to meet specific functional needs, but, in addition, they have certain features that make them attractive, thus satisfying the desire for beauty in the home.

The early American type (Fig. 163) shows the influence of the stockade, with its second floor projecting over the first, its low-pitched roof, and its shuttered windows. The New England colonial (Fig. 164) seems to fit into the cold, snowy New England climate. Roofs are cut off flush with the house to prevent ice and snow barriers from forming on projecting roof sections. This type radiates economy, but it has lived because of its beauty of proportion and its simplicity of detail. The Dutch colonial (Fig. 165) reflects the traditional economy of the Dutch people

in the maximum use of space. It suggests the early American influence in projecting walls and shuttered windows. The Eastern and Southern colonial (Figs. 166 and 167) and the formal Georgian (Fig. 168) seem to be suitable only for larger houses and may have limited use in farm homes of the future. The Western ranch house fits into the West and the Southwest, with its broad prairies or its rocky terrain, and shows the influence of Spanish architecture (Fig. 169). Farm homes of modernistic design (Fig. 170) are increasing, but this design requires

FIG. 168.—Formal Georgian architecture.

skillful architectural treatment in order to make it fit into its surroundings.

210. Recommendations for Planning.—Plan the home from *within* to suit everyday needs. Give consideration to special or occasional needs according to their importance. It would not be good practice to design the house to meet the requirements for some particular annual occasion or event, because everyday needs are of much greater importance. If sufficient flexibility can be built into the house to make it meet everyday requirements and special requirements, too, then the plan will be all the more valuable.

When the size and shape of the different rooms have been decided upon and the rooms have been grouped to form the best possible relationship, it is time to consider the type of architecture best suited to the house in its particular environment. If it

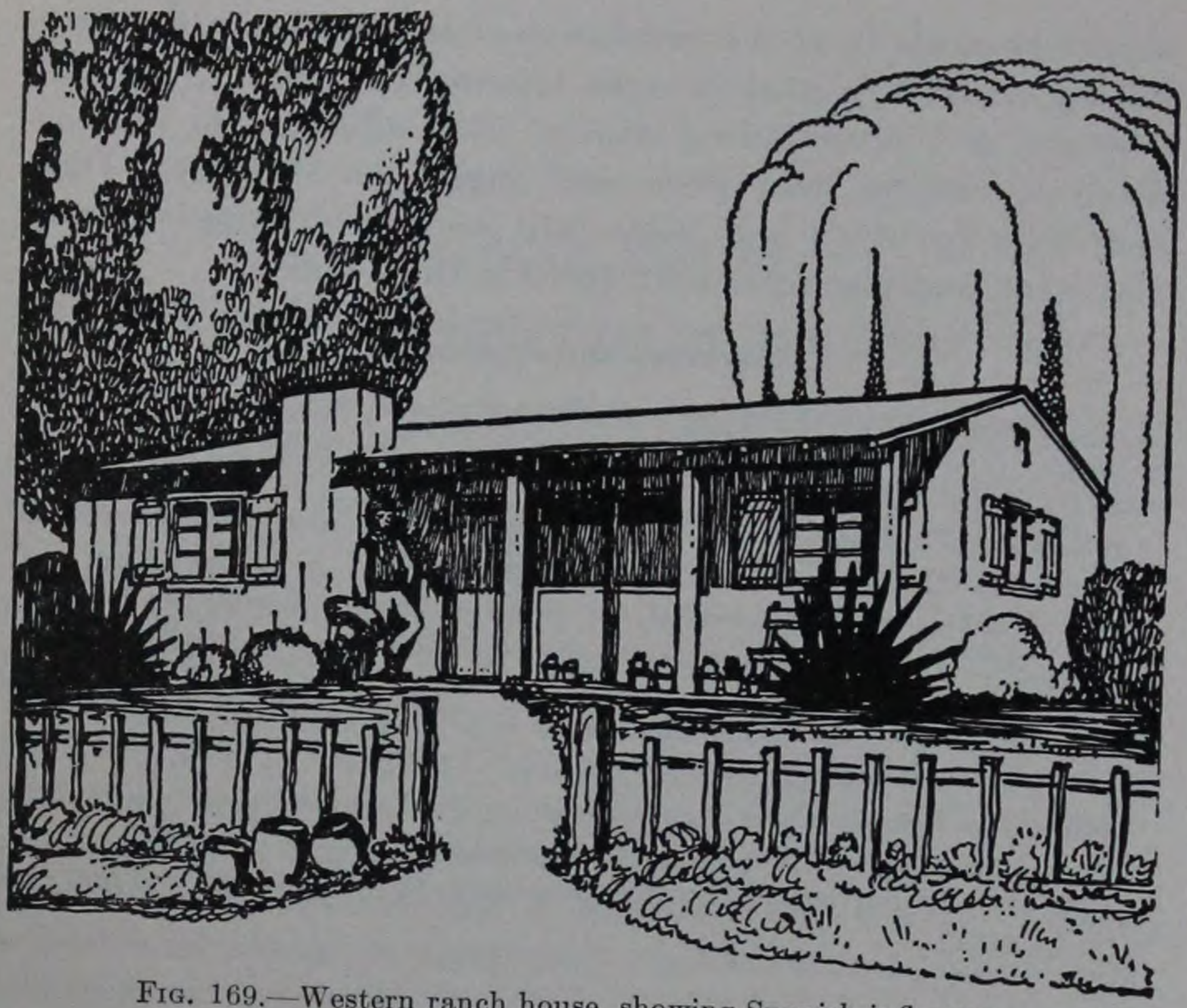


FIG. 169.—Western ranch house, showing Spanish influence.

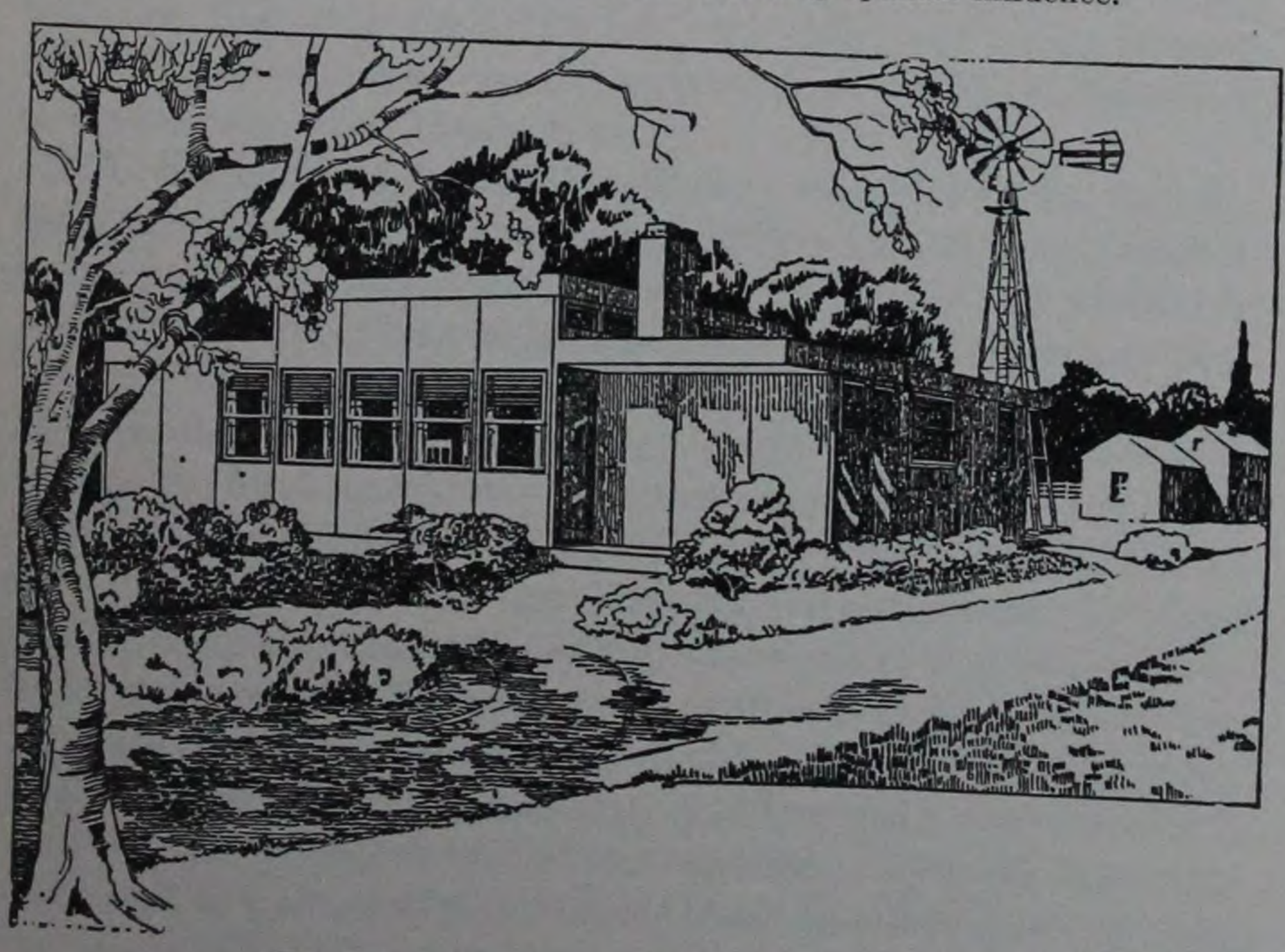


FIG. 170.—Farmhouse of modernistic design.

cannot be made to be representative of any particular type, it is usually possible to work in some feature that will at least place it in one of the recognized classes. The effort so far has consisted of making floor plans and suggestive sketches. These must now be taken and made into working drawings showing size, kind, and placing of each piece in the building.

Questions and Problems

161. Some authorities believe that the actual cost of modernizing a home is no greater in the country than in the city. Secure all the information you can on the subject.

162. Rate the different methods for securing efficiency in the farm home according to the importance of their contribution.

163. What is your opinion of the relative desirability of the kitchen-dining- and workroom combination as compared to the small efficiency kitchen for the farm home?

164. Does the recreation room deserve as much consideration in the farm home as in the home planned for the city?

165. Farm folk are more rugged than city dwellers, and therefore comfort in the home is not so essential. True or false?

166. Of what importance is attractiveness in the farm home, and how can it be secured?

CHAPTER XXXVII

DESIGN AND CONSTRUCTION OF THE FARM HOME

A large number of farms in the United States furnish, under present systems of management, a rather limited annual return to the operator. These farms are classed as grade *B* or *C* by the land-planning association. Farmers on these farms can afford the employment of a very limited amount of skilled labor, even in the construction of their homes. Several states are encouraging a "build-your-own" program and are giving instruction to farmers in carpentry, concrete work, plumbing, and wiring and giving supervision in a general way as the farmers erect their own buildings. Farmers on class *A* and some of those on class *B* farms have sufficient income so that their time may be utilized to better advantage in doing their regular business, and skilled labor can be hired to do construction work. This does not mean, however, that this group should not study and plan, because they will need to supervise and perhaps do a considerable amount of preliminary work themselves.

211. Excavation; Foundation Walls.—Excavation for foundations or for the basement, in homes where a basement is included, is one part of the construction that most farmers can profitably perform with their own help and equipment. If the house plan does not include a basement, the excavation will be limited to trenches dug for the foundation. These trenches should be as wide as the footings and of a sufficient depth to be safe from frost. If the plan includes a basement, the excavation is a more important item. Teams and slip scrapers, supplemented by hand digging to ensure accurate size and shape, make a good combination for the work. There are two methods used in placing the foundation wall. In one method the basement is dug to the exact length and width of the building, and the earth wall formed is used for the outside form for the concrete. In some cases this earth wall is treated with a coating of tar to aid in waterproofing the foundation. If a concrete wall is to be used, the next step

is to set and brace an inside form. The placing of the concrete in the forms produces rather excessive pressure, especially if the concrete is dropped from the top of the form. Any movement of the inside form results in unecessary thickness of the wall and consequent waste of concrete. Small pieces of soil may cave in as the concrete is poured and go unnoticed, causing trouble later.

Where foundation walls are built of field stone, the earth wall serves as a form against which the stone is placed, just as is done in ordinary cobblestone construction.

If the other method of foundation-wall construction is followed and both inside and outside forms are to be used, the width and length of the excavation must be greater than the exact width and length of the basement in order to make room for the installation and removal of the forms. The inside and outside forms can be wired together at intervals to prevent spreading. There is no waste of concrete with this method, the concrete is kept clean and free from dirt, and many times the concrete is better protected from drying out than it is when placed against a dry earth wall.

Brick and tile foundations may be built against an exact-sized excavation, or the excavation may be made larger than the building and the wall built up independent of the earth wall. Mortar joints can be pointed and a waterproofing treatment applied on the outside if needed.

212. Footings should be constructed very carefully, because any slight settling of the structure will cause cracking of plaster, sagging of doors and windows, or possibly damage to structural members. Drainage around footings is essential in many localities. These drain lines ensure a uniform moisture content in the soil at all points along the footing and help prevent uneven settling (see Fig. 171).

213. Center supports for the first-floor joists, if not carefully designed, may be a source of trouble after the building is completed. Many plans provide for a central wood girder. The joists are supported by the girder on one end and by a 2-in. sill on the other. The sill may shrink possibly $\frac{1}{16}$ in. as the lumber dries out and seasons, and the 10-in. girder may shrink as much as $\frac{5}{16}$ or even $\frac{1}{2}$ in. This allows the house to settle more in the center than at the sides, causing damage. The steel I-beam and

post shown in Fig. 171 eliminate this difficulty and are often used on this account.

214. Sills.—Treated lumber is often used for sills, especially if the foundation is low. Ordinary lumber may be treated for

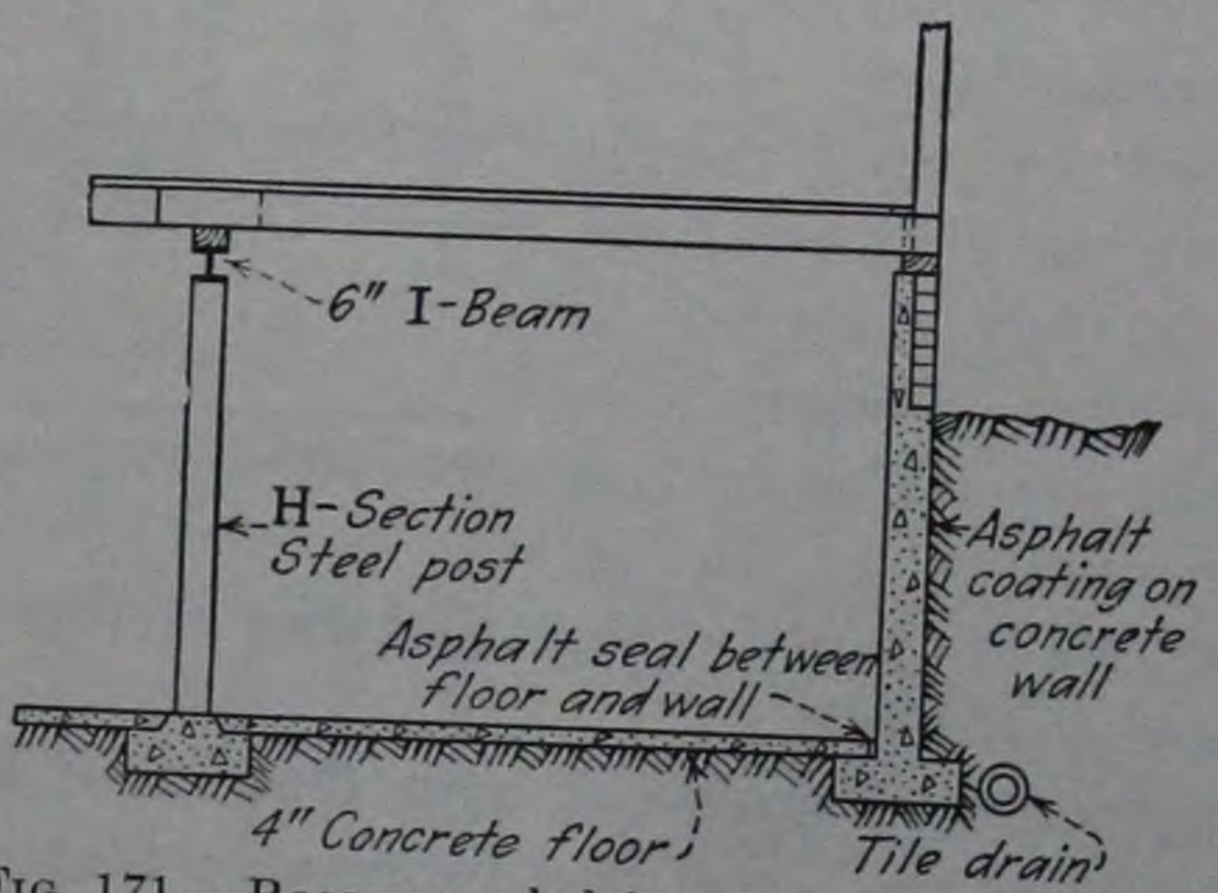


FIG. 171.—Recommended foundation construction.

this use if desired. When the usual solid-wall foundation is used, a 2-in. sill provides a straight, even surface for floor joists and furnishes a convenient means for fastening the joists and other structural members in place. The sill for a building having

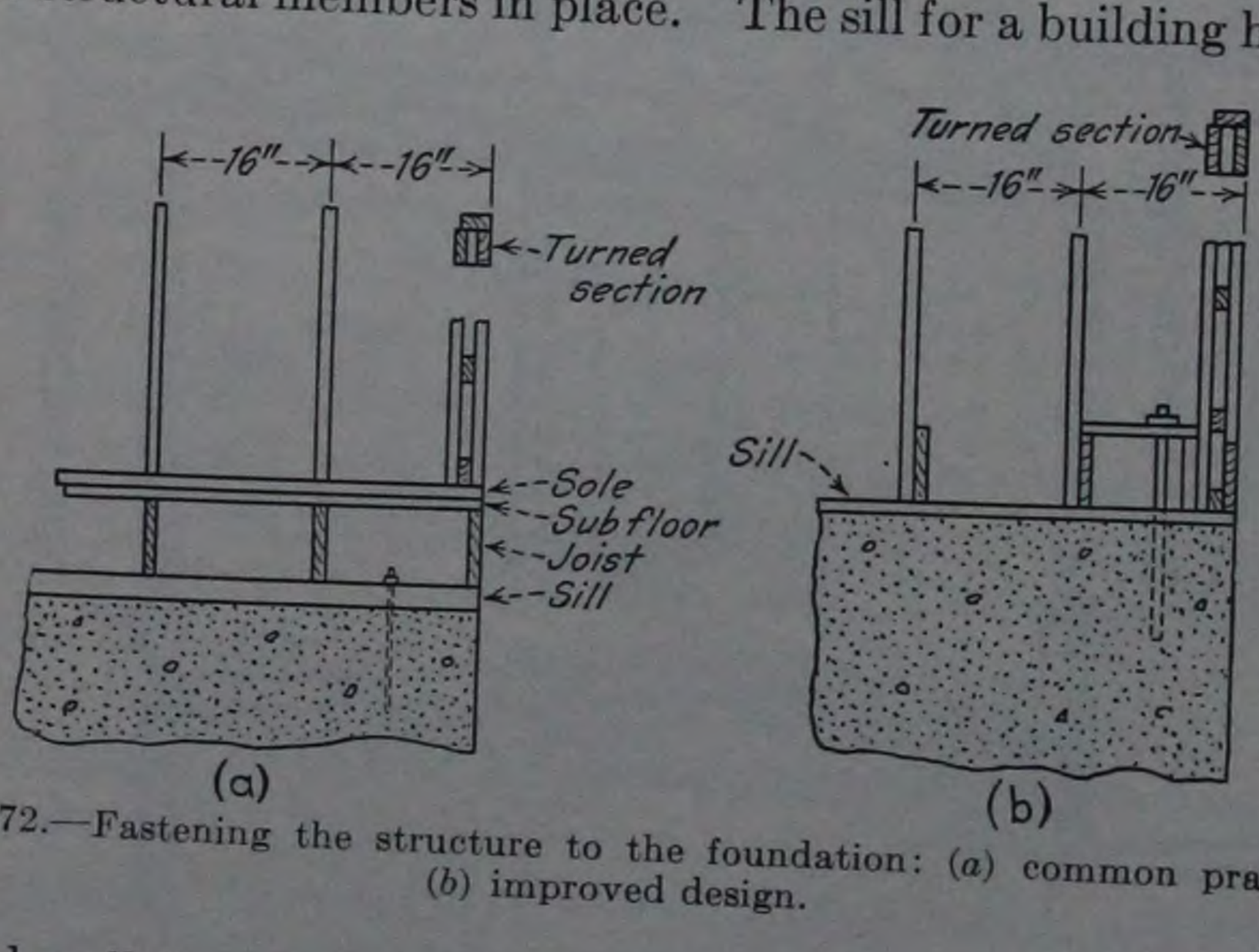


FIG. 172.—Fastening the structure to the foundation: (*a*) common practice; (*b*) improved design.

a solid wall foundation does not carry the load as a beam and therefore needs only sufficient depth to provide a good nailing surface. It should be wide enough to give sufficient bearing surface for the joists to prevent crushing the wood in either the

sill or the joist. Sills are usually made of 2- by 6-in. stock. To ensure even contact on the foundation and to prevent air leaks into the basement, the sill should be bedded in fresh mortar when placed.

215. Fastening the Structure to the Foundation.—Much of the damage caused by wind storms arises from the fact that buildings are not adequately fastened to their foundations. Figure 171*a* shows common practice in bolting the sill to the foundation. In Fig. 171*b* is shown an improved design that has several advantages over the common practice.

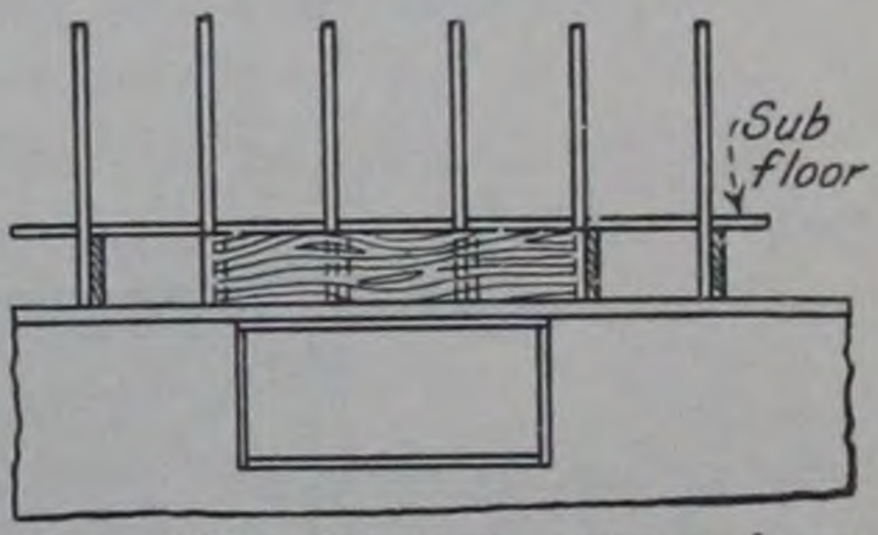


FIG. 173.—Support over a basement window.

216. Strengthening Framework over Openings; Partitions.—Openings in outside walls and partitions often leave a section of

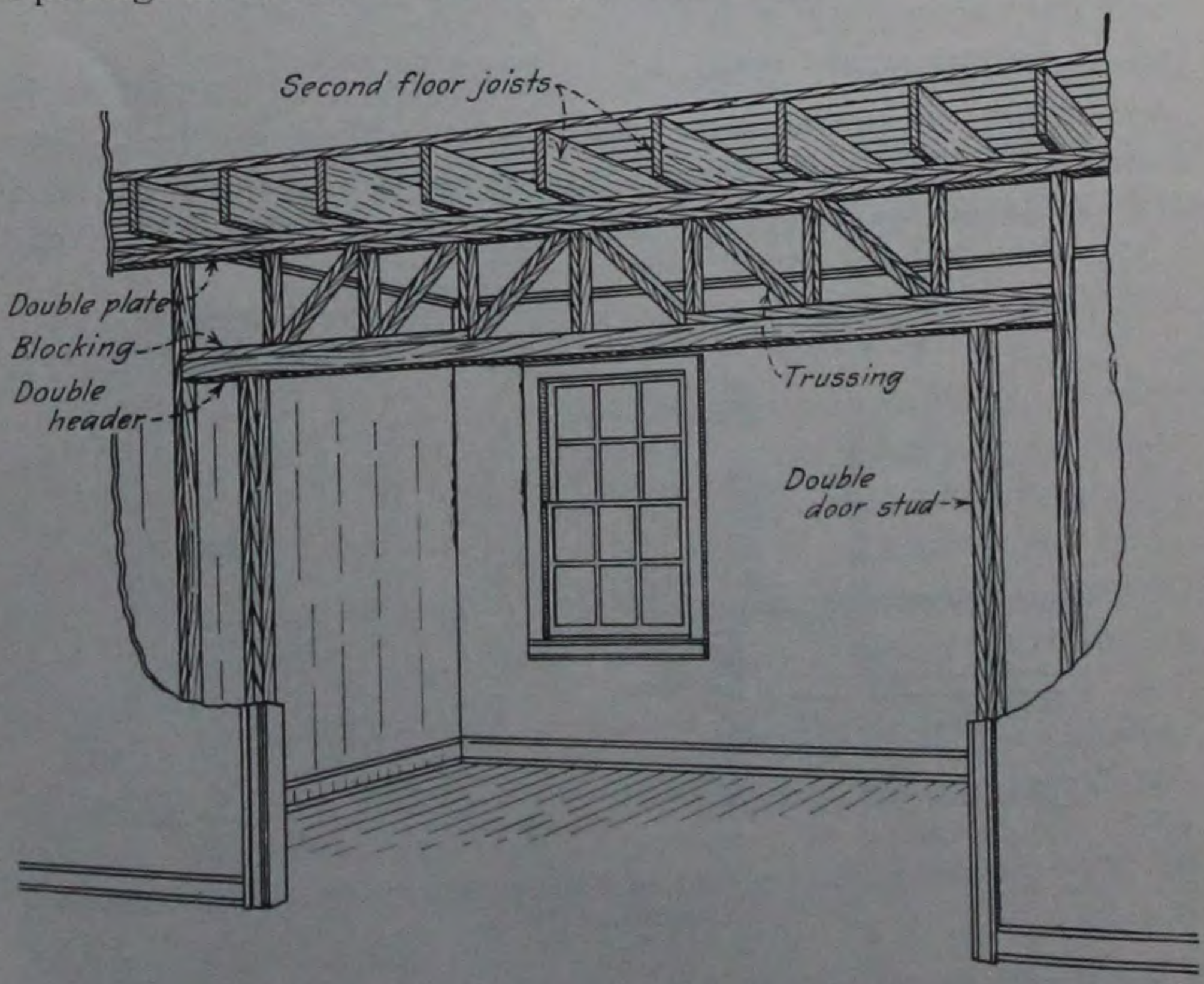


FIG. 174.—Trussed construction over a wide door.

wall with insufficient support. The wider the opening and the greater the load on the wall the more important the design. The

wall above the opening for a basement window can be supported as shown in Fig. 173. The two-by-eight shown does not interfere with other construction and is placed in a position to carry the load safely.

Wide doors in inside partitions weaken the wall unless adequate support is provided. Usually, however, there is sufficient depth above the opening to use wider stock than is necessary with narrow openings or a built-up truss to carry the load. Figure 174 shows trussed construction over a wide door.

Partition walls should be placed over partitions on the floor below if possible. If this cannot be done conveniently, the partition wall should be built as a truss supporting the load at each end. Such a trussed partition wall may be constructed so as not to add strain to joists below, or it may even be connected to support the floor below. Many contractors set the studs on proper spacing and then cut them out where openings are needed. Headers are nailed in place as shown in Fig. 175.

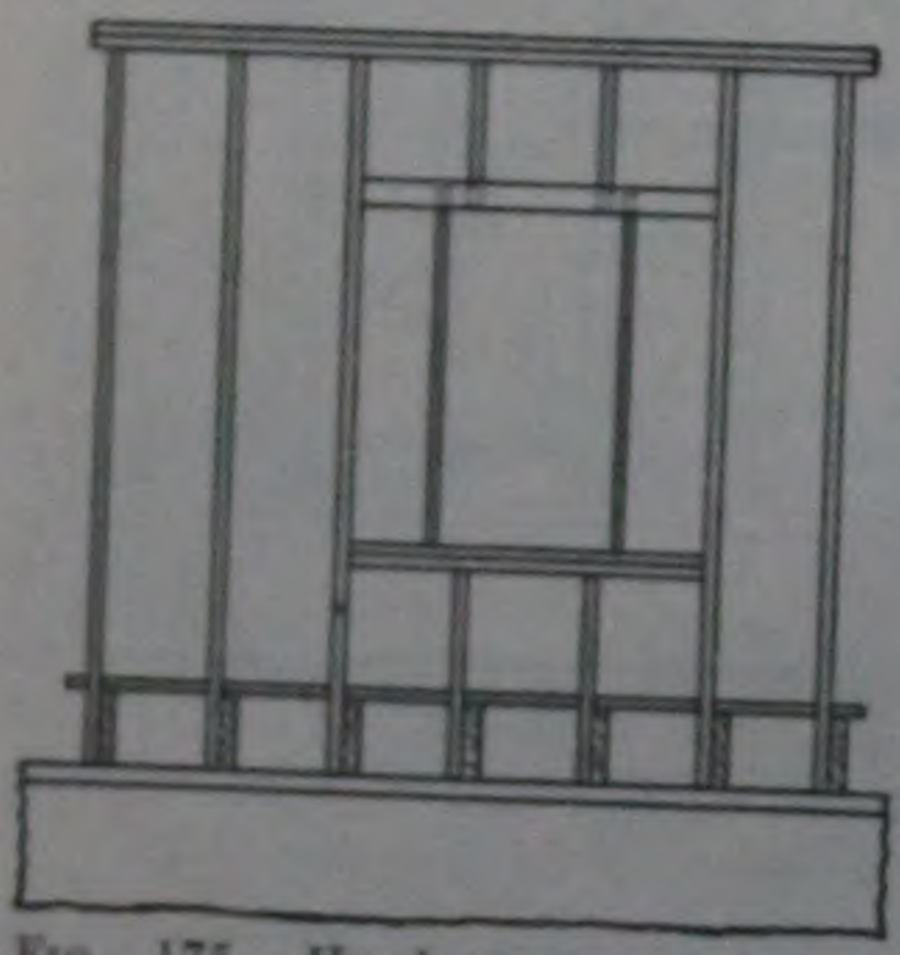


FIG. 175.—Headers over window openings.

217. Bracing can be accomplished in balloon-type construction by applying the wall sheathing diagonally instead of horizontally (see Fig. 176*a*). This method requires an additional amount of labor and results in more waste of material, but the extra rigidity secured is worth while. "Cut-in" bracing is very satisfactory if it is installed carefully. Short pieces are cut to fit between studding, as shown in Fig. 176*b*. The solid *bridging* shown in Fig. 176*b* prevents studding from buckling when loaded, shortens convection currents in the wall, and acts as a fire stop.

Bridging of floor joists is necessary, especially where long joist spans are used. When properly installed, bridging stiffens floor construction and reduces deflection when a load is applied. If a uniformly distributed load were applied over the floor, bridging would probably add nothing to the total strength, but under a concentrated load at least one joist on either side of the one to which it is applied will receive a part of the load, thus increasing

the strength as well as the stiffness of the structure (see Fig. 177). Floor joists in dwellings are designed for a loading of from 40 to 75 lb. per square foot.

218. Floors.—The subflooring, usually 1- by 8-in. shiplap, is laid at an angle of 45 deg. with the joists. This gives a bracing effect, especially for the second floor, and also gives a better

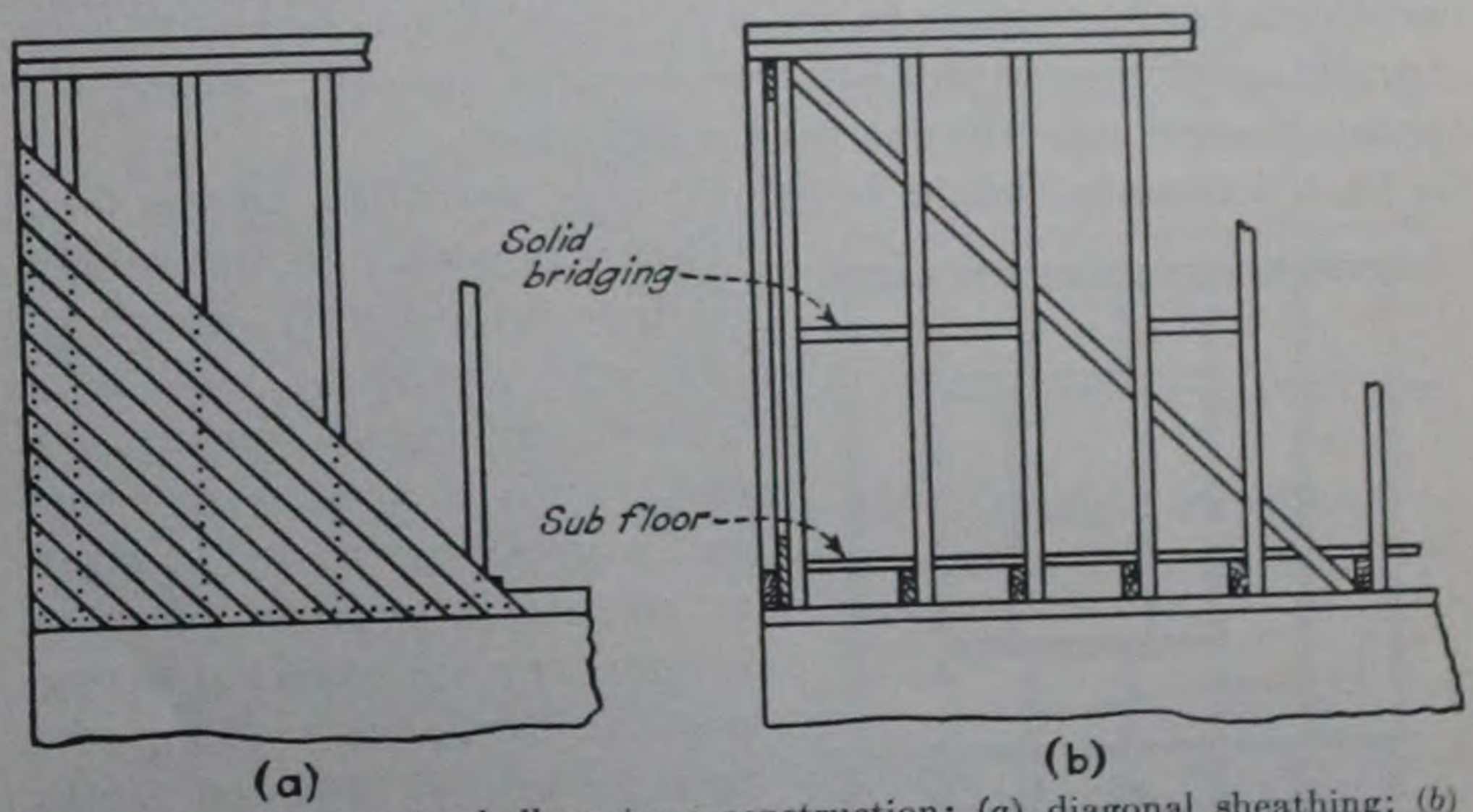


FIG. 176.—Bracing for balloon-type construction: (*a*) diagonal sheathing; (*b*) "cut-in" bracing.

bearing surface for the finish floor. The subfloor is used as a floor during the construction of the building until after the plaster has been applied and cured. It is then cleaned and covered with felt paper, ready for the finish floor.

219. Stairs.—Locating and planning stairs in a two-story house is always a problem. The designer is tempted to save space on

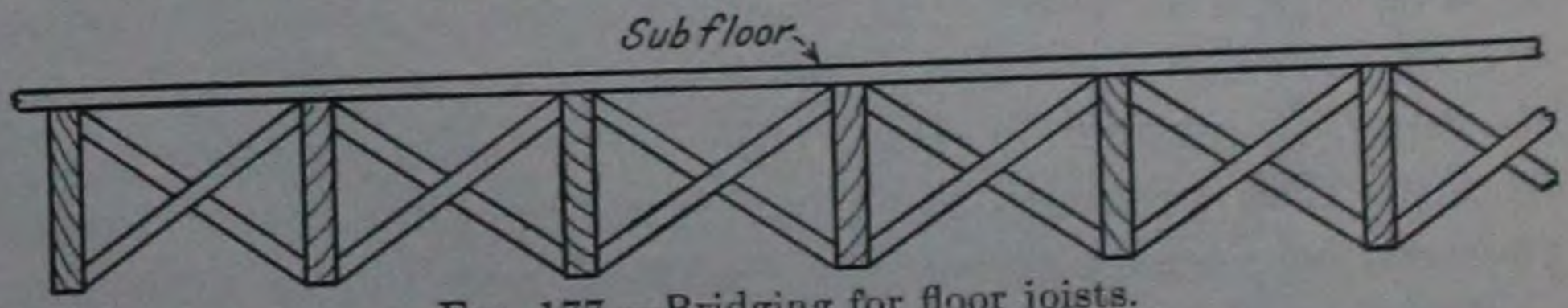


FIG. 177.—Bridging for floor joists.

stairways, and as a consequence he often makes the stairs too steep for comfort and safety. A riser of 7½ in. and a tread of 10 in. form a stair that is as steep as is consistent with safety. In the house with 8-ft. 6-in. ceilings and 10-in. floor joists, 15 steps will be required in the stairway. Therefore a floor space 13 by 3½ or 4 ft. must be given over to the stairway alone.

Landings at the top and bottom require an additional 4- by 4-ft. space on each floor. A two-direction stairway, as shown in Fig. 178, may be used in houses with limited floor space. This

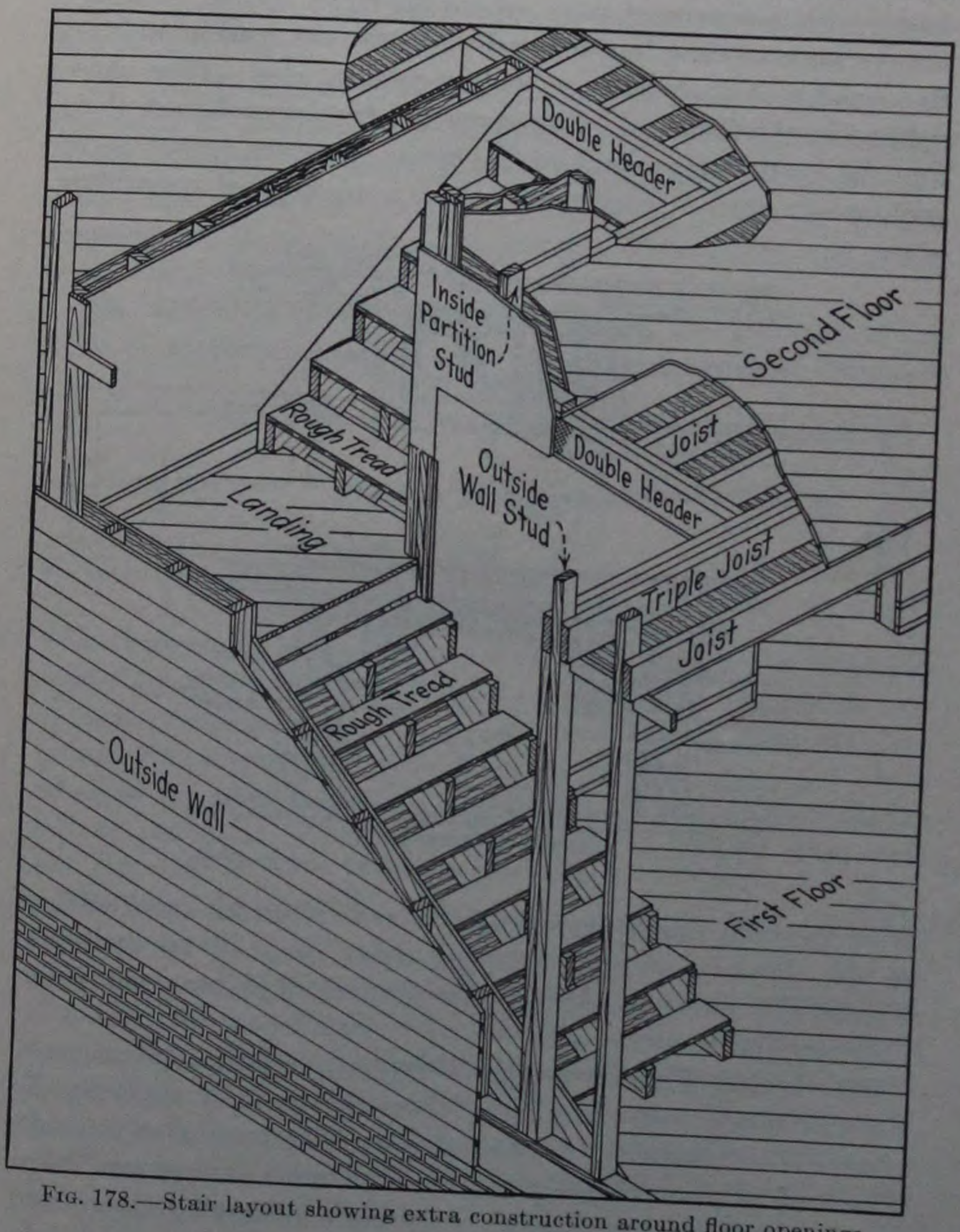


FIG. 178.—Stair layout showing extra construction around floor openings.

type of stairway is more expensive to build, however, than a straight stairway, and it is not so safe in everyday use but may utilize floor space to better advantage. The finish risers and

treads are nailed in place over the rough treads to secure adequate strength and stiffness.

220. Chimneys and Fireplaces.—The chimney in a two-story house with a basement may exceed 30 ft. in height. There is always some settling in this depth of brickwork, and in addition, the weight of the chimney, being concentrated, often causes settling in the footings. Chimneys and fireplaces should, therefore, be built independent of the main structure except at the roof, where it is necessary to make a waterproof connection.

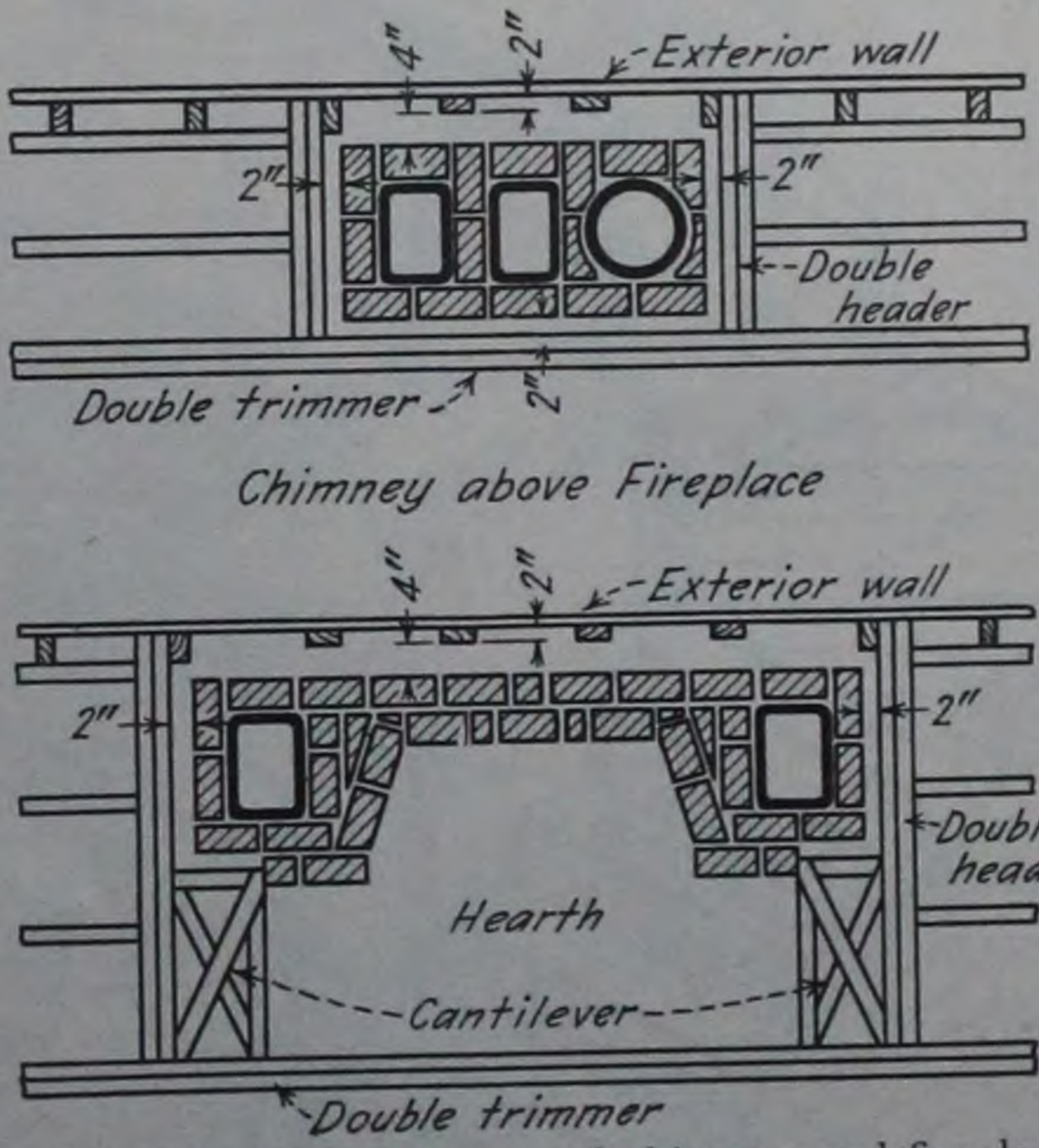


FIG. 179.—Framing around chimney and fireplace.

Roof flashings should be installed so as to allow for some settling of the chimney without affecting other parts of the building. Figure 179 shows headers installed to carry floors around the chimney and fireplace.

221. Inside Wall Covering.—Plastering is probably the most popular inside wall covering. When the work of applying the plaster is well done, the finished wall is attractive and serviceable. The work of plastering requires expert labor, however, and it has the further disadvantage of sometimes damaging floors and introducing a great deal of moisture into the house.

A number of substitutes for plaster, among them celotex, masonite, maizewood, plywood, and sheet metal, are gaining in popularity. These substitutes also have some disadvantages,

most of which come from the absorption of moisture and the consequent swelling, shrinking, and warping of the material. When some of the defects are overcome these improved products will no doubt be used much more extensively, especially in low-cost construction.

222. Inside-finish lumber should be selected to conform with the type of architecture chosen and add unity to the inside design. Figure 180 shows different types of finish lumber available. One of these types should be selected to suit the type of architecture characterizing the house. Baseboards and other trim should conform.

223. Windows must be selected and located to conform to the style of architecture chosen for the house. Colonial windows,

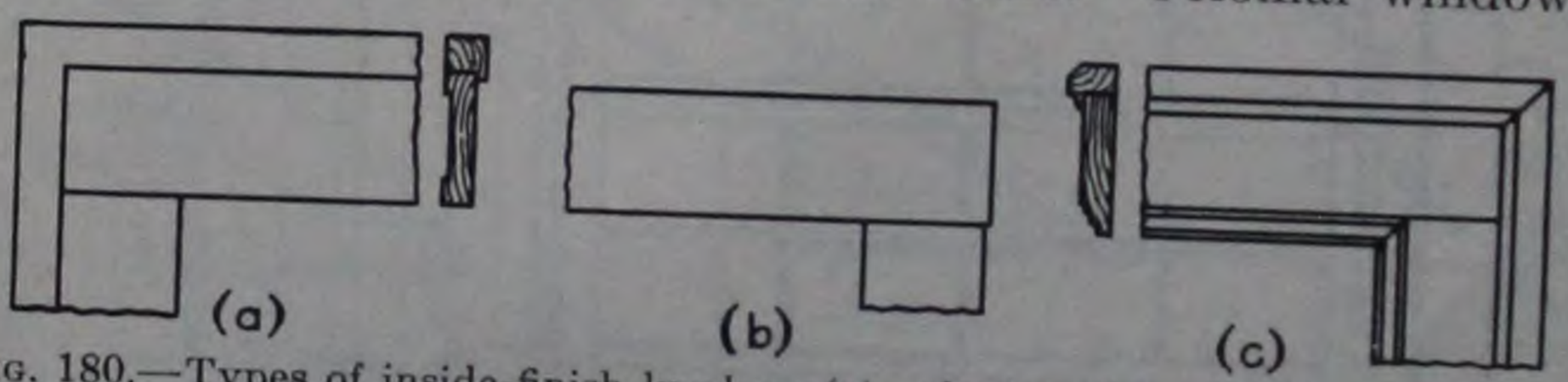


FIG. 180.—Types of inside-finish lumber: (*a*) colonial; (*b*) mission; (*c*) artcraft.

with their small panes, fit into a colonial design, and windows consisting of one large piece of plate glass may be used effectively in modernistic designs. Single windows rather than multiple groups characterize the New England colonial homes. Corner windows are often used with modernistic designs. Either check-rail or casement windows are available in almost any style (see Fig. 181).

224. Roof design depends a great deal on the type of architecture selected. Although it is desirable to keep the roof as simple as possible, this purpose should not be carried to the extent of spoiling the appearance of the building. Many designs include dormers in the roof to give light and ventilation to upstairs rooms. These dormers may consist of raised sections in the roof, as in the Dutch colonial type of architecture; or they may consist of a gable dormer, as shown in the New England colonial; or the dormer may have a flat deck and a hip roof extending from this flat deck. Valleys are made waterproof by placing a strip of copper or galvanized iron on the sheathing and the shingles placed over it forming a closed valley; or the metal may be left partly exposed, forming an open valley. Roof mastic may be used to

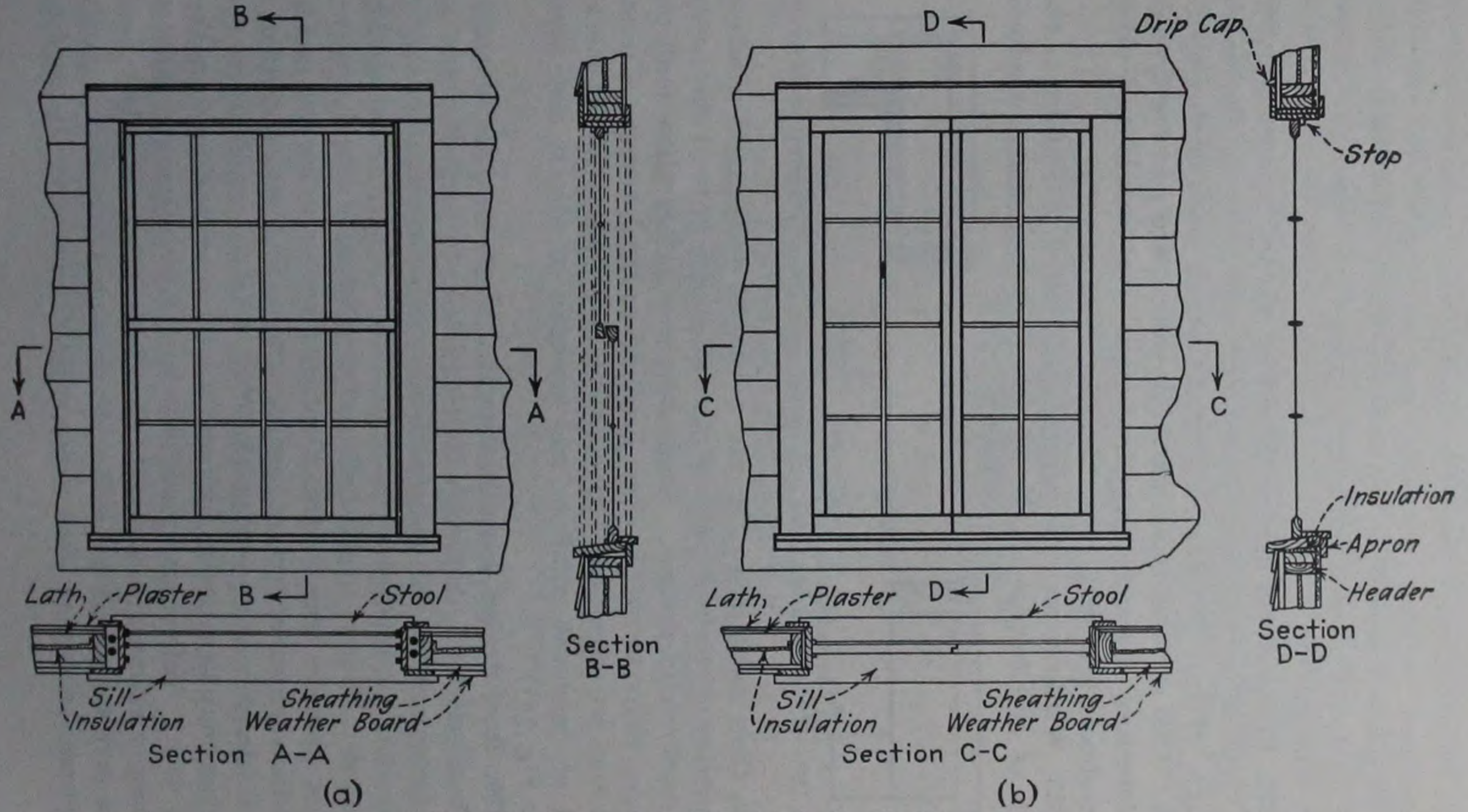


FIG. 181.—Types of windows: (*a*) check rail; (*b*) casement.

hold shingles in place and the necessity of nailing through the metal sheet avoided. Flexible shingles may be bent to fit over the ridge, but with other types of shingles a metal ridge roll is advisable. Modernistic designs sometimes use flat roofs. These are usually built up by use of alternate layers of roofing paper and roofing cement, although metal roofs with standing seam or soldered joints can be used.

Projection.—The amount of projection given a roof is dependent quite largely on the climate of the region. The wide projecting roof of the California bungalow, for example, prevents the sun's rays from reaching the walls, and therefore fills a definite

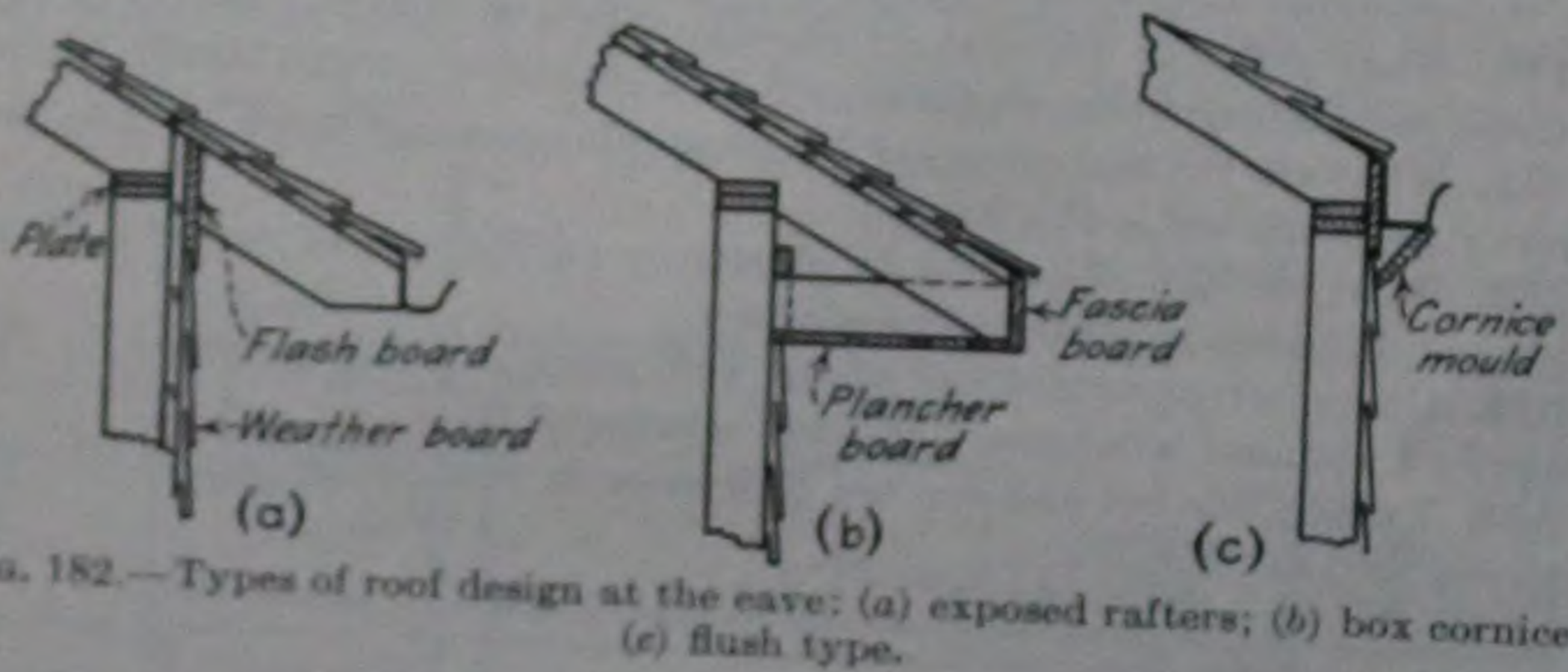


FIG. 182.—Types of roof design at the eave: (*a*) exposed rafters; (*b*) box cornice; (*c*) flush type.

need. In regions of heavy snow this projection would be very undesirable. Figure 182 shows three types of roof design used in different types of architecture.

The box-type cornice (see Fig. 182*b*) is typical of the Georgian type of architecture and is often used to make the building appear to be lower than it actually is. This is sometimes desirable if a full two-story house is built. The eave shown in Fig. 182*c* is used in many colonial designs. It enables a considerable saving in roof covering, and since insulation is being used extensively in walls the need for shading them is decreased.

The different kinds of insulation and the effectiveness of each have been discussed in Chap. XIV, but a few points may well be added here. Placing blanket, foil, or filler insulating material between studding or joists may be rendered less effective by neglect of a few important details. The space between window and door frames and the opening provided for them may be the point for considerable heat loss. A small amount of filler-type insulation packed between the frame and the studding, sill, or

headers will insulate this space and prevent much loss of heat and entrance of dirt to soil walls and ceilings. Packing the space between plates and roof or between joists at the wall on both upper and lower floors stops leaks at these points and enables the owner to get the best returns from his investment in insulation.

Questions and Problems

167. What are the factors that determine whether a farmer should hire a carpenter or do his own construction work?

168. What advantages does the farmer have over the city dweller when he constructs a home?

169. Settling cracks arise from uneven settling of the structure. What are the principal causes for this uneven settling?

170. What different features of construction will serve to decrease the damage to buildings from windstorms?

171. What are the bad effects of building chimneys and fireplaces into the interior partition walls of a house?

172. What are the objections to plaster as an inside wall cover? What are some desirable substitutes for plaster?

173. Under what conditions would you use check-rail windows in the home? Casement windows? Built-in windows?

174. Explain the reasons for the difference in roof projection in various types of architecture.

CHAPTER XXXVIII

WATER SUPPLY AND SEWAGE DISPOSAL FOR THE FARM HOME

225. Plumbing.—As soon as conditions are provided to prevent freezing in the house, water and waste disposal systems can be installed. Funds for home improvements sometimes come rather slowly, and it is often necessary to wait a number of years before these improvements can be financed and the home mod-

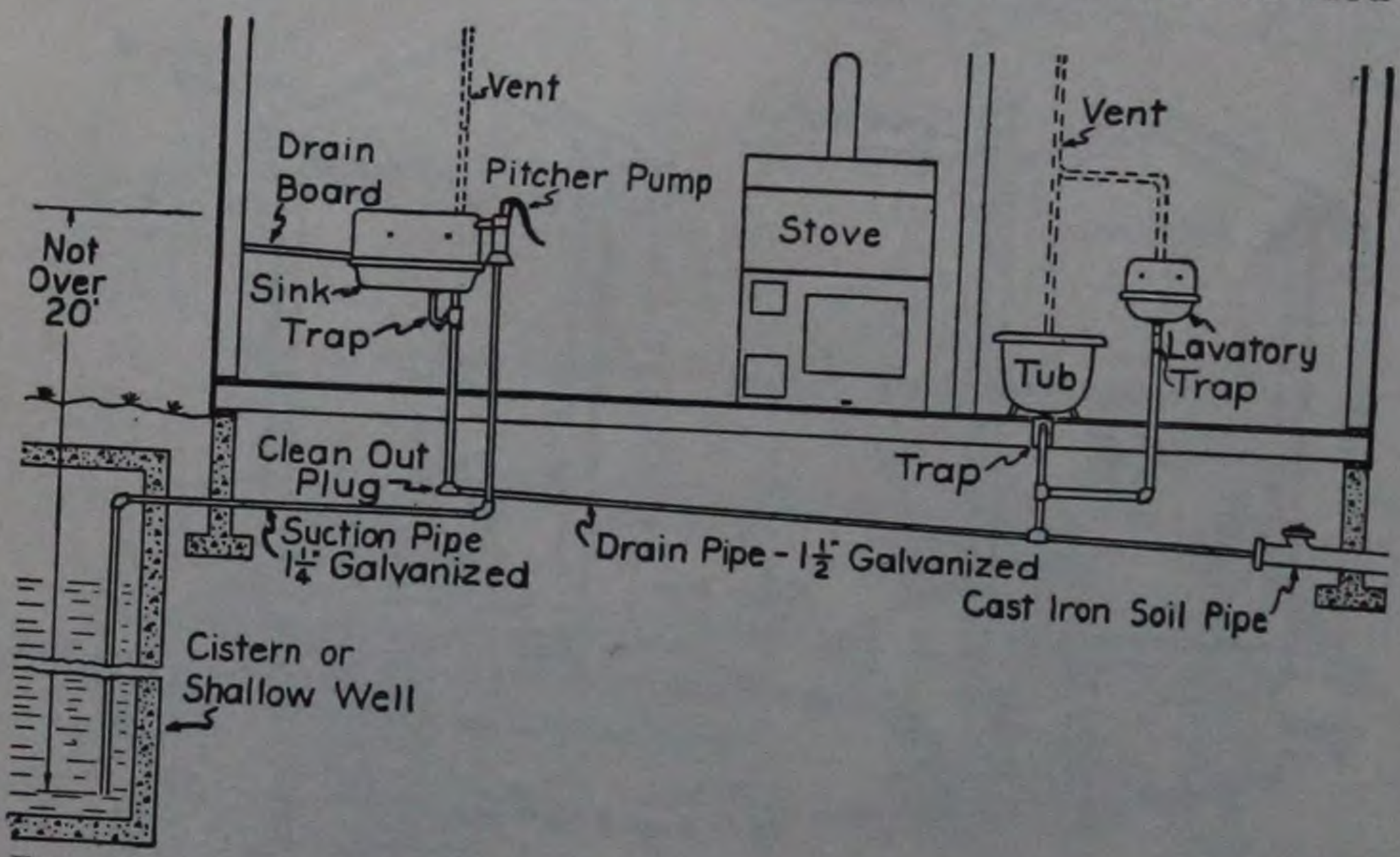


FIG. 183.—Pump, sink, bathtub, lavatory, and drain. An important step toward modernizing the home.

ernized. The Missouri Agricultural Engineering Extension Department advocates a plan for installing a modern system step by step over a period of years. Figure 183 shows the equipment used in making the first step toward modern plumbing in the home.

Step 1.—The pump, sink, bathtub, lavatory, and drain furnish a means of bringing water into the house and removing much of the waste that would otherwise have to be carried out. Water

can be heated on the stove and carried to the bathroom until such time as the complete plumbing equipment can be purchased. The pump is the only piece of equipment that will not be needed when the modern system is eventually completed. Figure 184 shows the disposal system for the drainage from the sink and

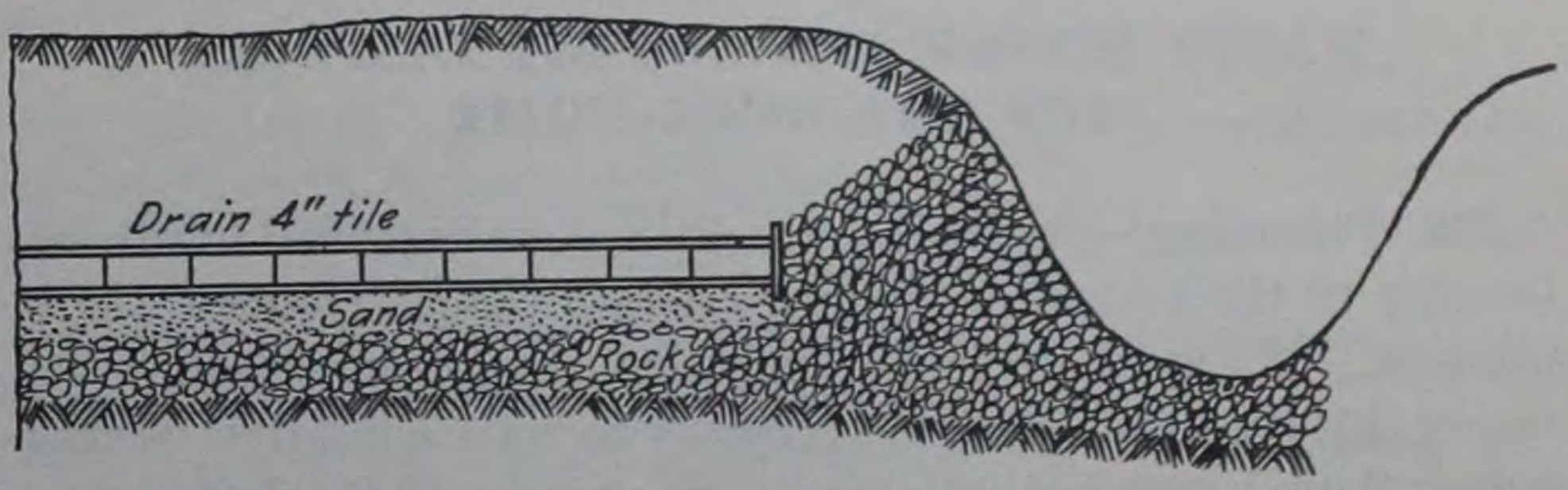


FIG. 184.—Outlet protected from freezing.

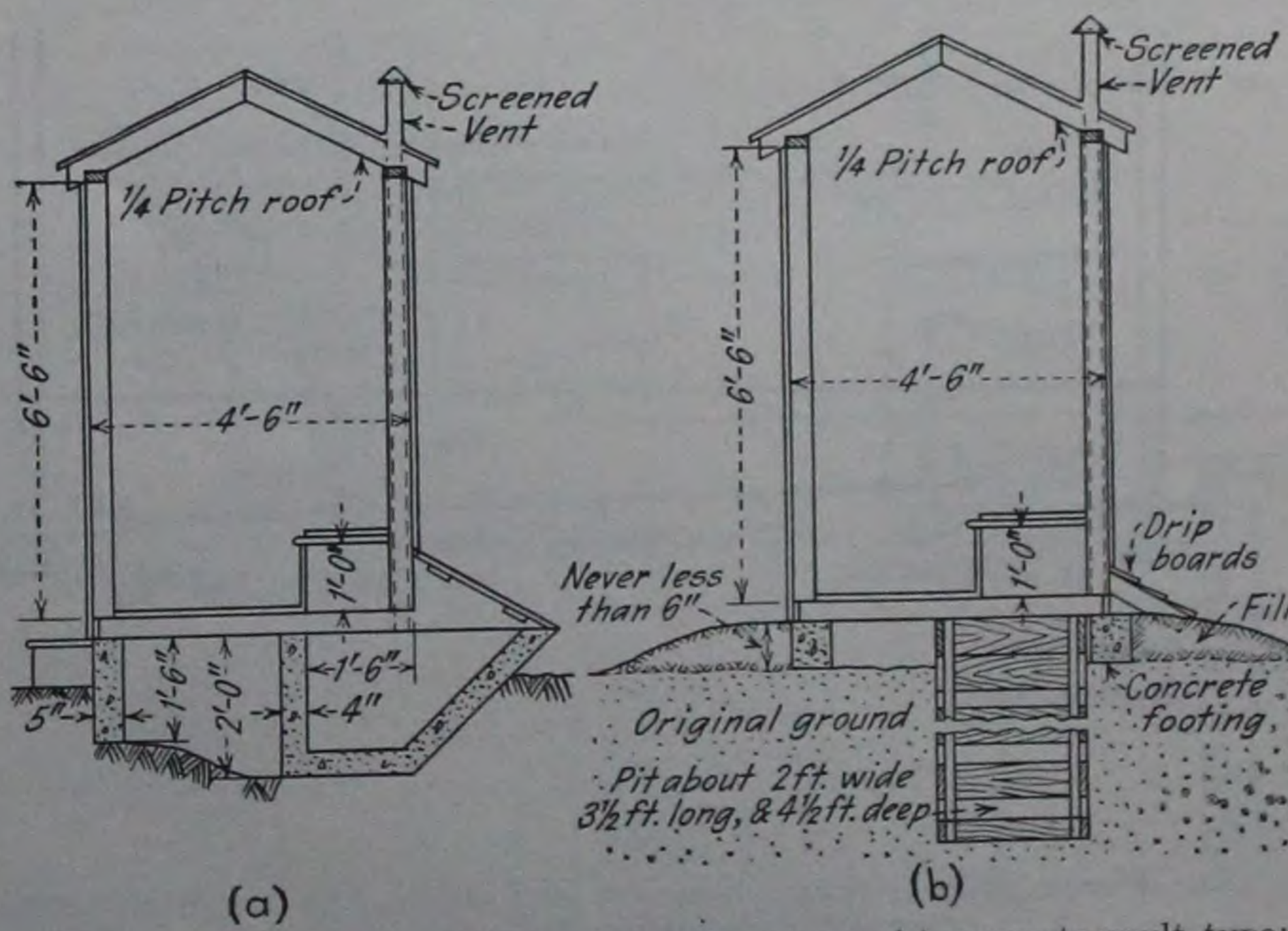


FIG. 185.—Two types of privies in common use: (*a*) concrete-vault type; (*b*) earth-pit type.

bathtub in a location where an open drain is available at a safe distance from the source of water supply. The rock- or gravel-filled sump at the end prevents the line from freezing in the winter and provides a filter that improves conditions at the outlet into the open drain. The sewer line to this point and as much farther as is necessary to protect the water supply (150 ft. minimum) should be made of sewer tile (4 in., usually) with

cemented joints. The grade in the sewer line to this point should not be greater than 1 per cent and preferably less. The liquid in sewer lines on steep grades runs so shallow that material will not be floated, resulting in clogging. The other objection to

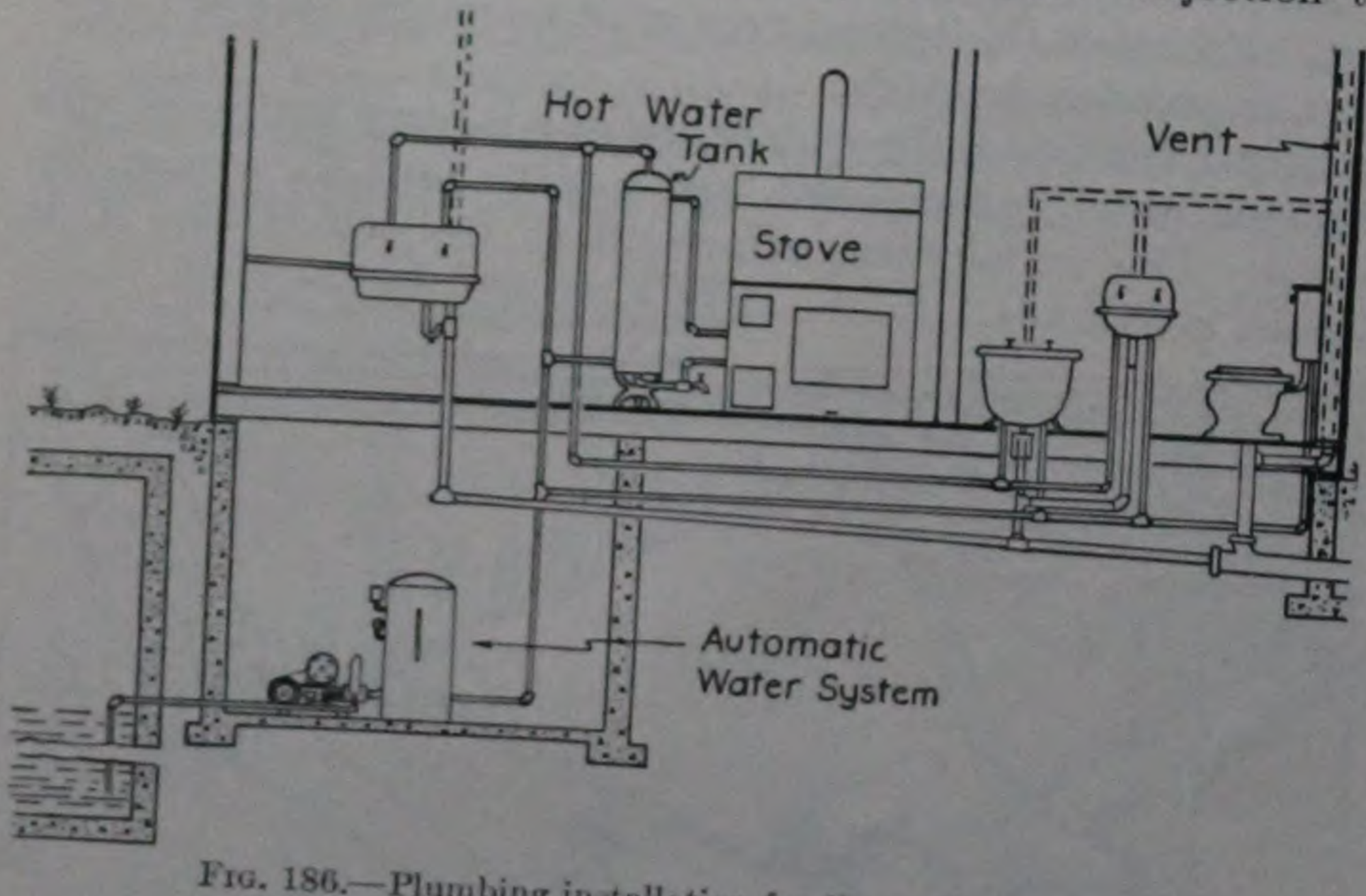


FIG. 186.—Plumbing installation for the modern home.

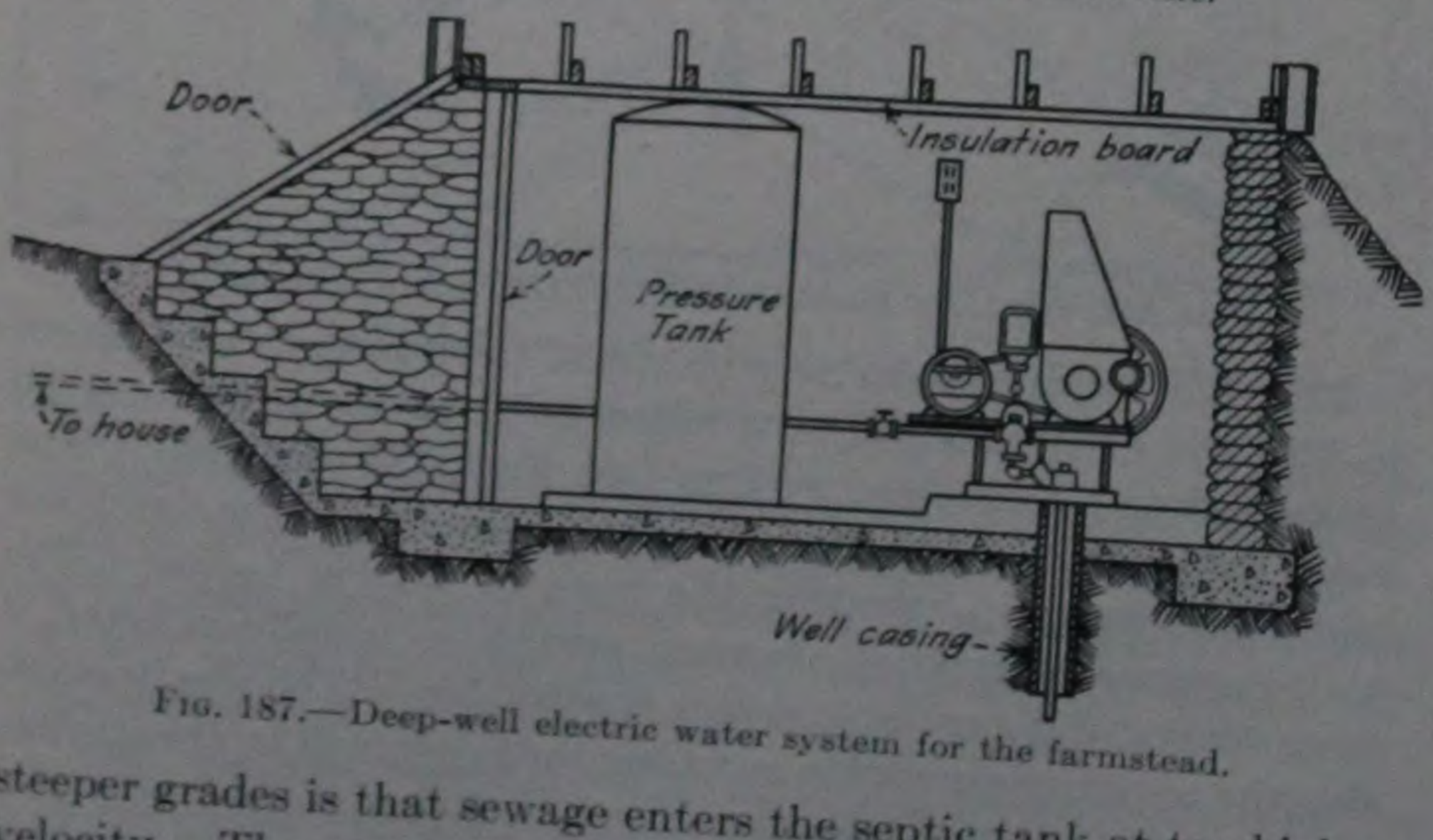


FIG. 187.—Deep-well electric water system for the farmstead.

steeper grades is that sewage enters the septic tank at too high a velocity. The sewer line should be placed carefully, because when the next step in home improvement is taken a section of the line will be removed and the septic tank installed, and this drain will then be a regular sewer line.

Until such time as the septic tank can be installed (step 2), some type of outdoor privy must be used. Two types are shown (see Fig. 183*a* and *b*), the first having a waterproof concrete vault that must be cleaned at intervals and the second an earth pit. Privies of this second type must be moved to a new location as occasion demands.

Step 2 consists of the installation of a modern bathroom with running water, indoor toilet, and a septic tank for sewage disposal. This installation, completed at the end of step 2, is shown in Fig. 184.

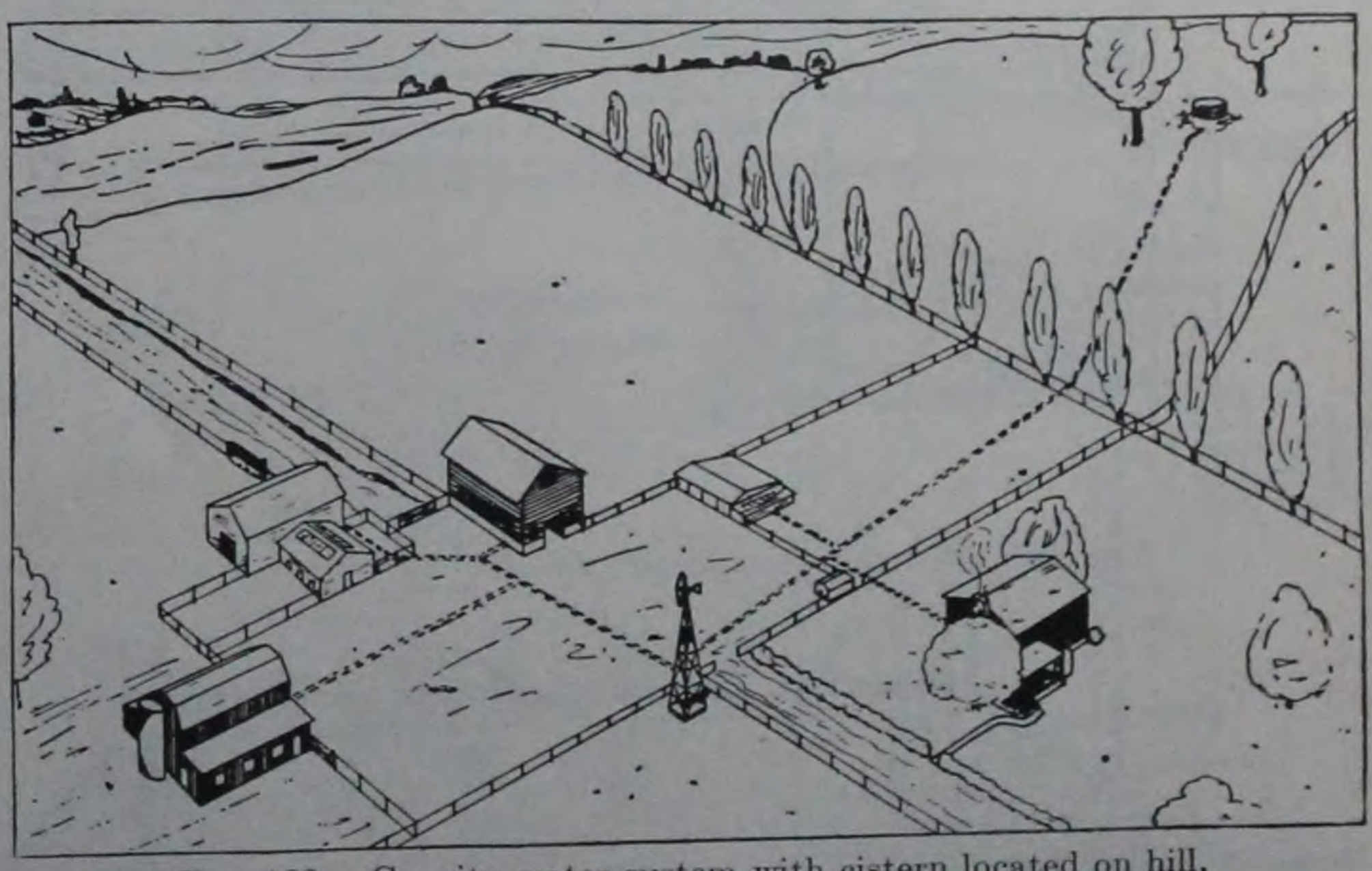


FIG. 188.—Gravity water system with cistern located on hill.

226. The water system may be one of the small systems shown in Fig. 184 used to supply the house only, or the house may be connected to a farmstead system (see Figs. 185 and 186). The kind of power available and the topography of the land are important items in selecting the type of system to use. The hydropneumatic type of pressure system is usually selected if some source of dependable power is available. The less dependable the source of power for pumping the larger will be the storage requirement. If a windmill is used, a 6-day supply of water must be stored; with a gas engine, a 2-day supply; with current from a dependable high line, practically no storage is required. An electric-powered, frost-proof farmstead system is shown in Fig. 185. Such a system, once installed, provides a valuable

service with a minimum of attention. If there is a hill adjacent to the farmstead, an underground cistern could be located on it to furnish water under at least 10 lb. per square inch pressure (see Fig. 186). The water lines must be placed below freezing depth and frost-proof hydrants or insulated float chambers used to control water level in tanks in a satisfactory installation. The minimum pressure that will operate modern fixtures satisfactorily is 10 lb. per square inch. To secure an adequate flow

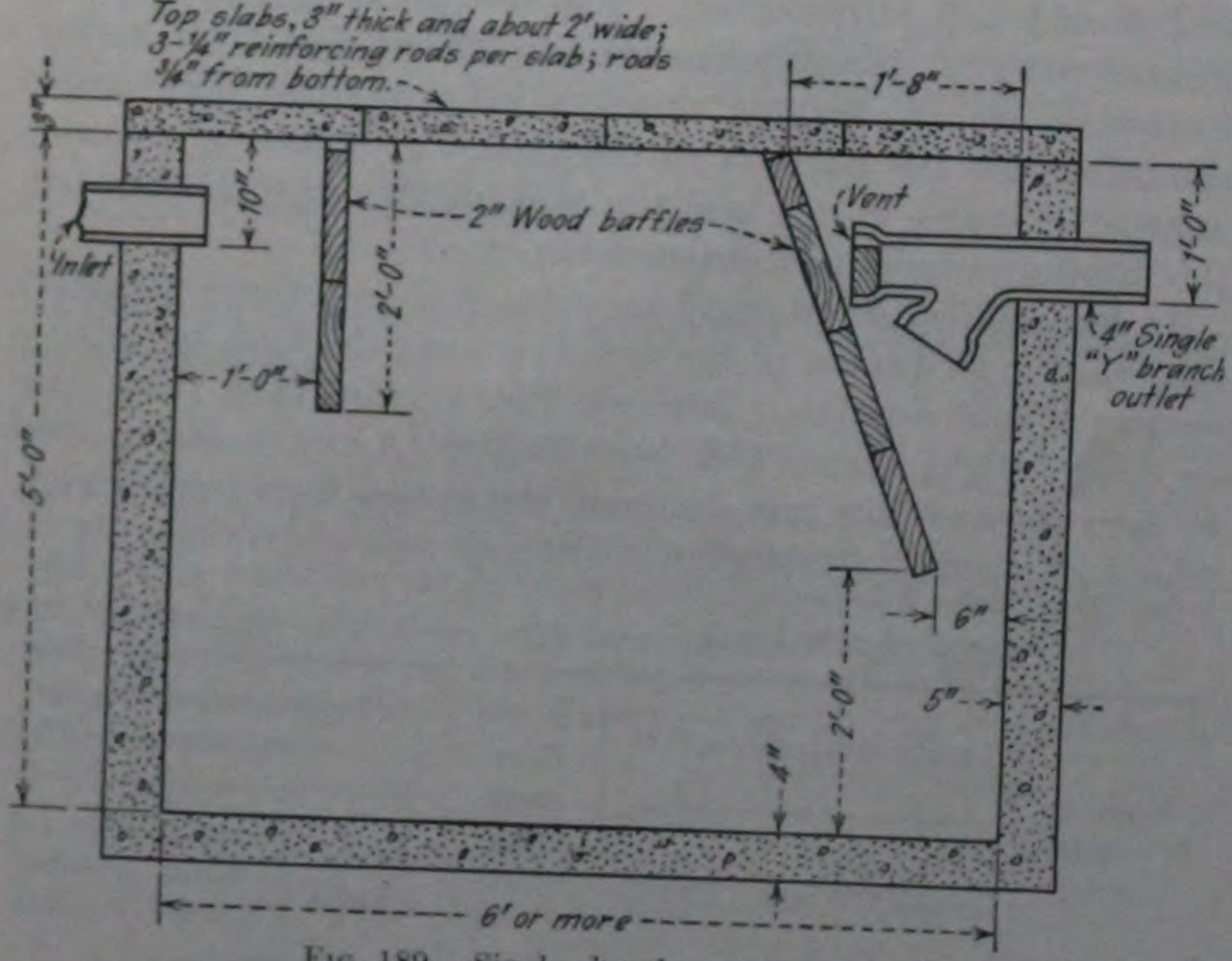


FIG. 189.—Single-chamber septic tank.

of water where such low pressures are used, 1-in. pipe and fittings will be necessary. Water under a pressure of from 20 to 40 lb. per square inch is desirable for cleaning dairy-barn and hog-house floors. It is also convenient for cleaning cars, trucks, and machinery and has some value in fire protection.

227. Sewage Disposal.—The plumbing installation completed at the end of step 2 is shown in Fig. 186. The stool is connected into the sewer line through the Y installed previously for this purpose. The sewer line is cut and the septic tank (Figs. 189 or 190) installed. It is necessary to maintain conditions in the tank so that the anaerobic bacteria present in the sewage may

break it down into carbon dioxide, soluble, and insoluble materials. The gases escape through vent pipes in the tank or through the outlet line, soluble materials are carried out in the overflow, and the insoluble materials must be removed from the tank at intervals of from 5 to 10 years, depending on the extent of use. Table 50 gives size of tank needed for different sizes of families.

Fats and oils rise to the surface of the septic tank to form a scum that acts as a seal. This forms between the two baffles and should not be disturbed. The sewage is broken down in from 36 to 48 hr., depending on the conditions for bacterial action. Excessive use of cleaning powders may produce unfavorable conditions for the bacteria in the tank. However, if an extra amount of water is run into the tank at the time of their use, the dilution usually prevents trouble.

In flat country or on small acreages, it is sometimes necessary or desirable to dispose of the overflow from the tank by using a system of subirrigation. Disposal lines are laid 14 to 18 in. deep on a very slight grade (1 in. per 100 ft.). A switch can be used to turn the overflow into different absorption lines from time to time to prevent waterlogging of the soil.

TABLE 50.—RECOMMENDED SIZE FOR SEPTIC TANKS

Number of persons served	Inside dimensions, feet			Concrete, cubic yards	Approximate amounts material required *		
	Length	Width	Depth		Sacks cement	Sand, cubic yards	Gravel, cubic yards
7 or less	6	3	5	2⅛	13½	1⅛	1½
8–10	7	3	5	2⅜	15	1¼	1¾
11–14	8	3	5	2⅝	16½	1⅜	2

* Based on a 1-2¼-3 mix, using 5 gal. of water per sack of cement with sand of average dampness.

Another plan is used where the whole absorption system is flooded intermittently. The two-chamber tank shown in Fig. 190 is used when such a plan is necessary. The overflow from the first chamber is collected in the second and is held until there is a sufficient amount accumulated to activate the automatic siphon This allows all the water accumulated to flood the subirrigation

system and provide uniform distribution. This second chamber is made to hold from one-third to one-half as much as the first, causing the disposal field to be flooded once each day. In locations where the desired absorption field or an available drain is on higher ground than the septic tank and where electricity is

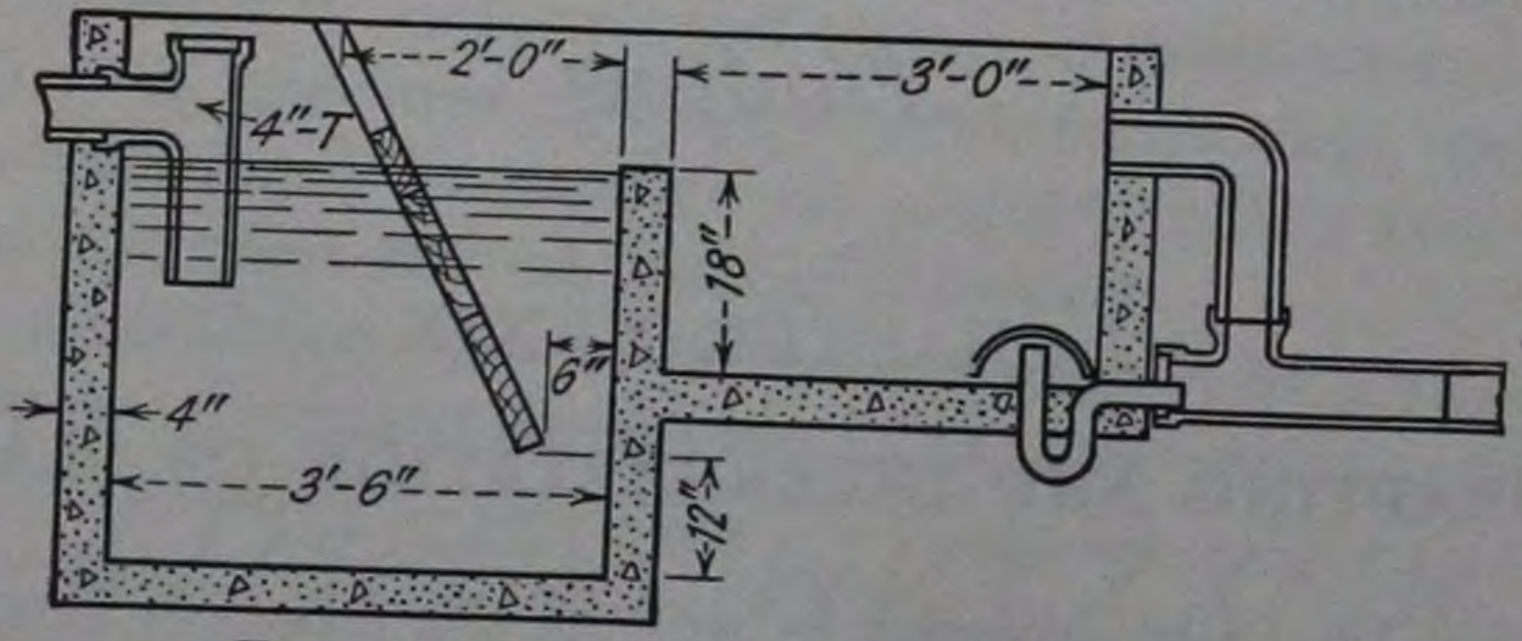


FIG. 190.—Double-chamber septic tank.

available, an automatic sump pump may be used instead of the automatic siphon.

Questions and Problems

175. What are the steps in the Missouri system of home modernization, and what are the advantages of this sytem?

176. What would be your choice of a water system for a farmstead (*a*) if electric power were available? (*b*) If a windmill were to be used?

177. What becomes of the sewage after it enters the septic tank?

178. What are the advantages of the two-chamber tank over the single-chamber tank?

PART VIII

Drafting

CHAPTER XXXIX

DRAFTING AND INTERPRETATION OF PLANS

The modern agriculturist as well as the engineer has need for a knowledge of drafting. He is required many times to make plans for structures and equipment to fit into his system of management for an enterprise. If he is to make himself understood and if he is to secure from the builder the kind of building or device he desires, he must be able to put his ideas into a working plan. If he isn't able to do this, he must stay with the builder and give him constant direction throughout the building

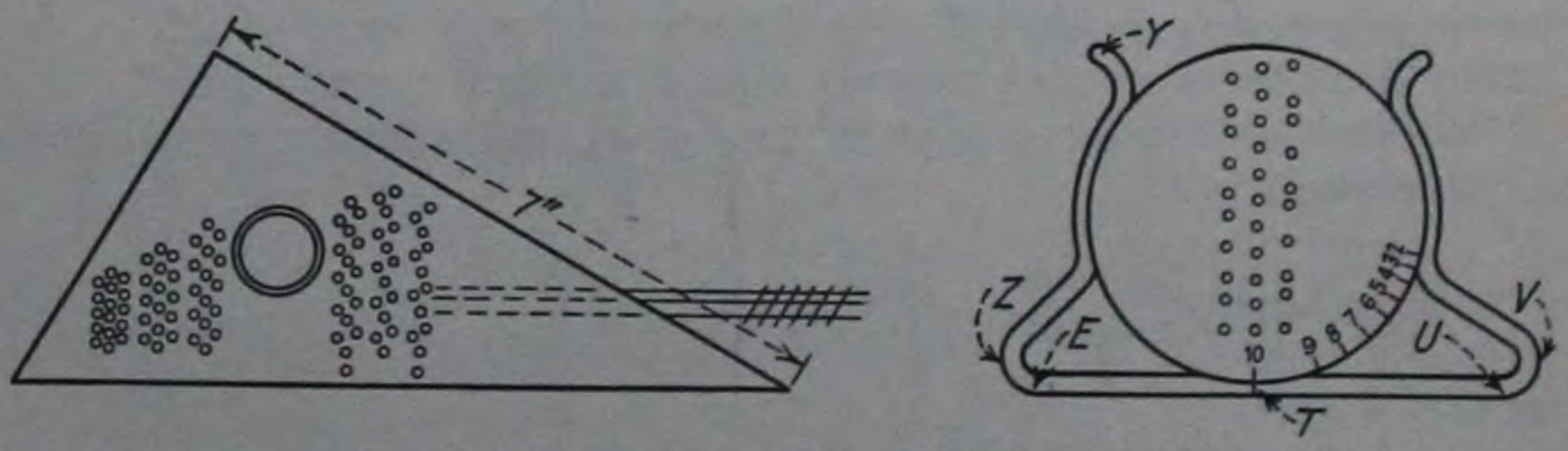


FIG. 191.—Equipment for ruling guide lines for lettering.

period. Languages change from one country to another, but the language of a good working drawing is universal.

A great majority of present-day farmers must do a considerable amount of their own construction work because of financial limitations. Farmers, rich or poor, however, must be able to take advantage of developments in building plans; they must be able to build or supervise construction if they are to keep abreast of the times in their field of business. Each farm has need for special features in its buildings to fit the enterprise, the operator, or the topography of the land. If the farmer is unable to develop these special features himself, he must be content with stock

plans made to fit the average conditions and with the resulting average efficiency.

228. Lettering.—The first requirement of a draftsman is that he be able to do a high-class job of lettering. Lettering is said to be an art; if we refer to perfection, then this is probably true, but if we refer to uniformity of style and neatness and clarity in lettering, it becomes merely a proficiency that the average person with a will to practice can acquire. This skill will come only with a great deal of practice, however.

The *slant Gothic* style of lettering seems to be a favorite with draftsmen. Its slant is similar to that of script, and it lends

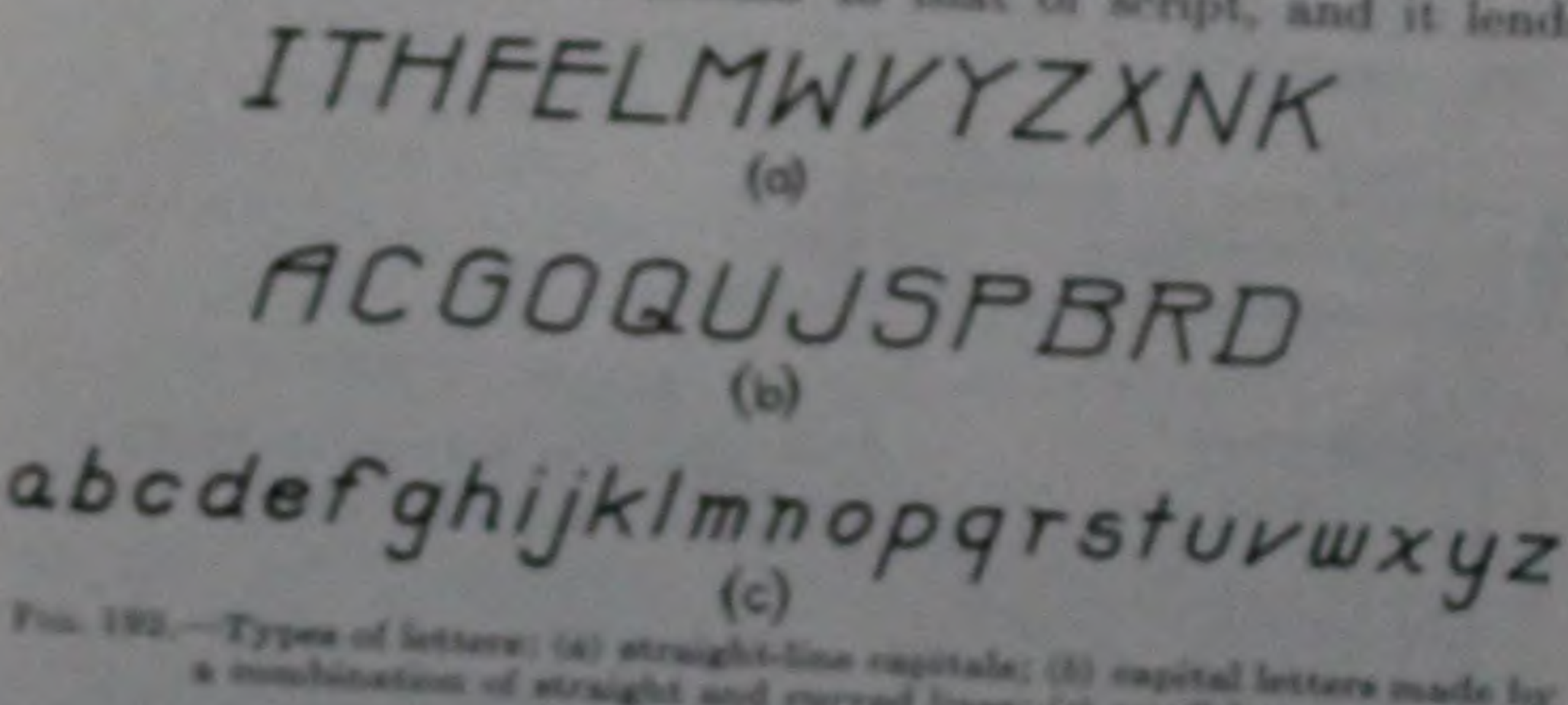


FIG. 192.—Types of letters: (a) straight-line capitals; (b) capital letters made by a combination of straight and curved lines; (c) small letters.

itself to speed. The characteristic lines of each letter are made at an angle of 15 deg. with the vertical.

Guide lines are necessary for good lettering, regardless of how experienced the draftsman may be. These horizontal guide lines, three for each line of letters, are drawn by means of a straightedge or other lettering tool. The space between the top and bottom lines is equal to the height of the capital letters, and the center line, two-thirds the height of the capital letters, determines the height of the small letters. Special equipment in the form of lettering triangles or a lettering tool can be purchased for laying out or ruling guide lines and slant lines and will enable the beginner to start off correctly (see Fig. 191).

Capital letters are perhaps more difficult to make than small letters and require more practice. Small letters are similar to writing and for that reason are relatively easy to make. Certain capitals such as I, T, H, F, E, and L, composed largely of straight lines, should be mastered first and then the more difficult letters

practiced. The width of most letters is two-thirds their height. The areas between letters in a word should be approximately equal. The area between words should be twice that between letters. The letter I is difficult to fit into a word, but if the rule of keeping equal areas between letters is followed the spacing will be taken care of. The letters A, V, Y, Z, X, N, and K come in the class of straight-line letters (see Fig. 192*a*).

The next group of letters is made up partly of straight lines, but some skill is required in connecting up the straight-line parts with the proper curves. The letters O, C, G, Q, U, J, and S come in this class (see Fig. 192*b*).

The small letters are less difficult than the capitals, but even so, to secure uniformity of size, height, slant, and spacing, a great amount of practice is required (see Fig. 192*c*).

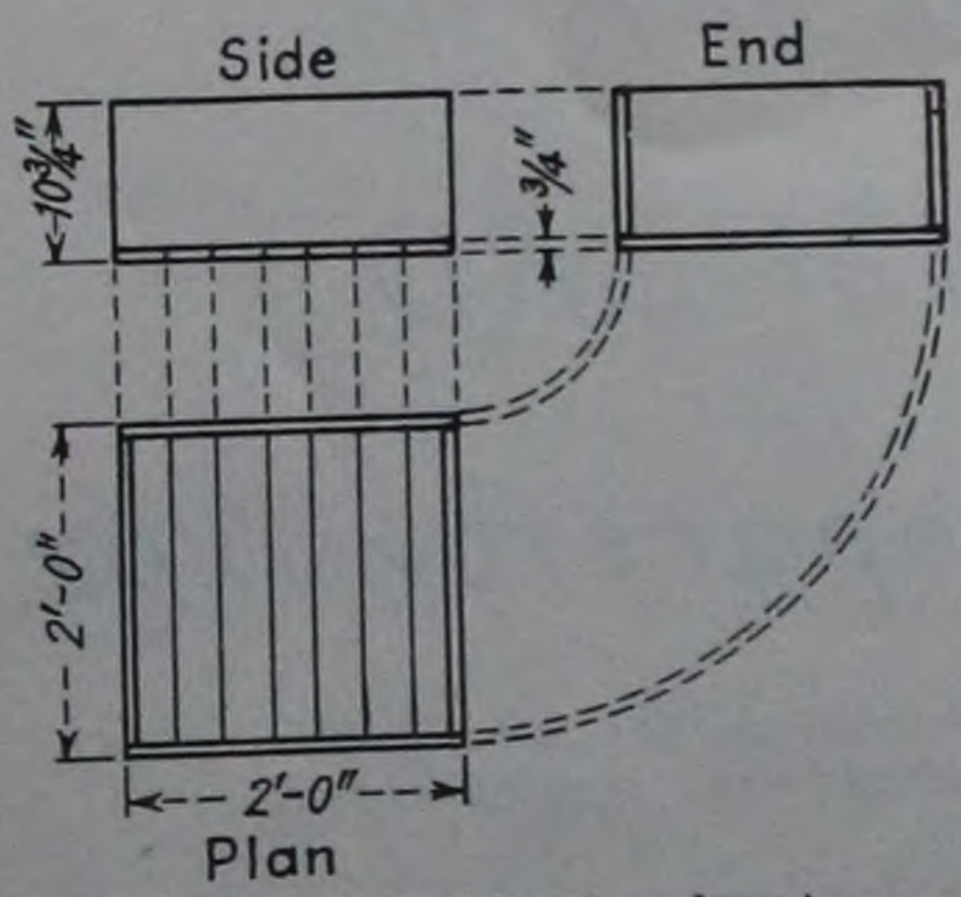


FIG. 193.—A projection drawing.

KINDS OF DRAWINGS

229. Projection drawings are used almost universally as working drawings. They can be dimensioned to show major lengths and sizes, and they can be measured to determine sizes not given, provided the scale to which the drawing is made is known. This type of drawing is called a *projection drawing*, because after the plan view is made the other views can be projected from it at least in part. Figure 193 shows a plan view of a box with the side and end views projected from it. The width of the side view and the joints between floor boards were projected directly from the plan view. The over-all width and the thickness of side boards were projected through a 90-deg. angle for the end view.

Dimensions are usually given by the methods shown, but if dimensions of any part are not given, the drawing may be scaled to determine the size of the piece.

230. Isometric drawings are used very largely for illustrating conceptions that are difficult to express in a projection drawing. Three sides of the object are shown in one drawing, which aids in giving an idea as to the relationship of parts (see Fig. 194).

Many draftsmen follow the plan of using projection drawings for the main working drawings and isometric drawings for showing details. The isometric drawing is not pleasing to the eye, because the drawing does not present the object as it actually is or as it seems to the eye. The drawing is based on the following rules:

a. All vertical lines are drawn vertical.

b. Horizontal lines extending to the right and left are drawn at a 30-degree angle with the horizontal.

231. Oblique drawings are similar to isometric drawings except for the fact that one face is drawn parallel to the horizontal base

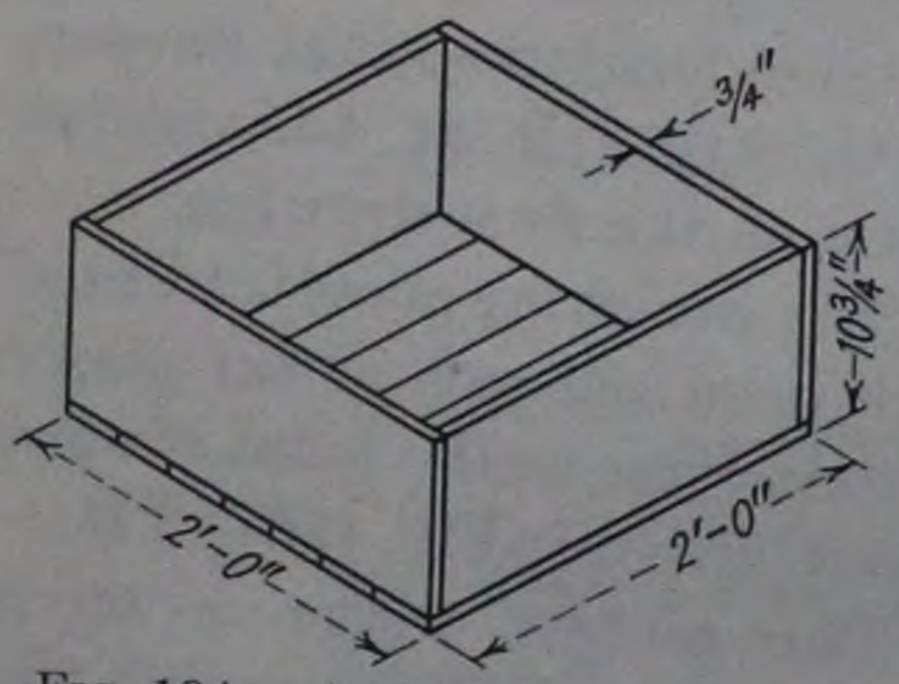


FIG. 194.—An isometric drawing.

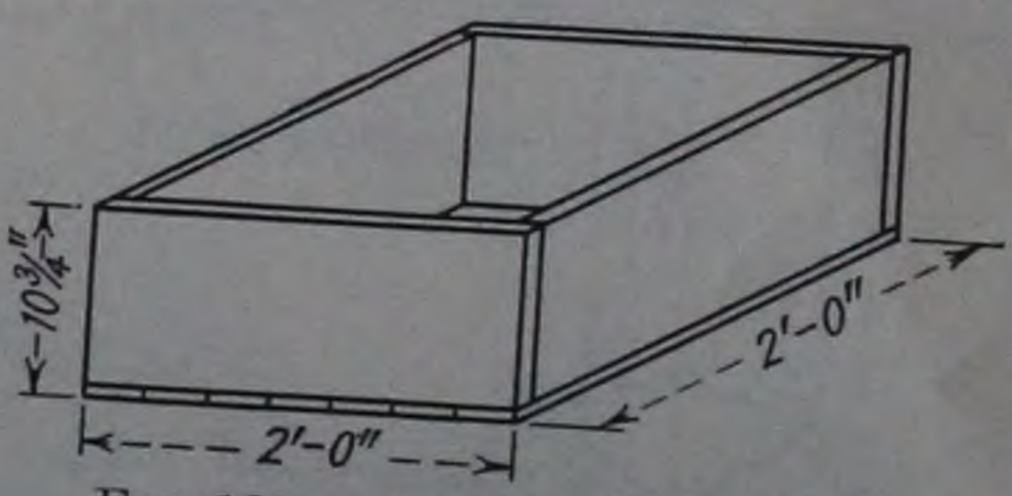


FIG. 195.—An oblique drawing.

line (see Fig. 195). This face is the same as the same view in a projection drawing. The remainder of the drawing is similar to the isometric with one difference: the face opposite the one drawn parallel to the main axis is also drawn parallel instead of at a 30-deg. angle as in the isometric.

Many times the details needed can be shown on the end view. (This view may be scaled to find dimensions not marked as in a projection drawing.) The oblique drawing enables the draftsman to give a better idea of what the piece of work will look like when completed than could be given with an equal amount of work applied to projection drawings.

232. Perspective drawings show objects as they appear from the particular point of view selected. A perspective drawing is an illustrative drawing particularly useful because it gives a better idea of the appearance of the finished product than any of the previously mentioned types of drawings. A knowledge of perspective aids in illustrating work for publication, either by freehand sketches or regular perspectives.

Making the Setup for a Perspective Drawing (see Fig. 196).

a. The *plan view* is placed on the drawing board at any desired angle.

b. The *point of view* is located as far from the nearest corner of the plan view as the point of observation selected is from the object. In Figure 196 the point of view is located 5 ft. from the nearest corner of the plan view and directly in front of it. The distance must be laid off to the same scale as is used in the plan view. The vertical line from the point of view to the corner of the plan view is called the *principal axis.*

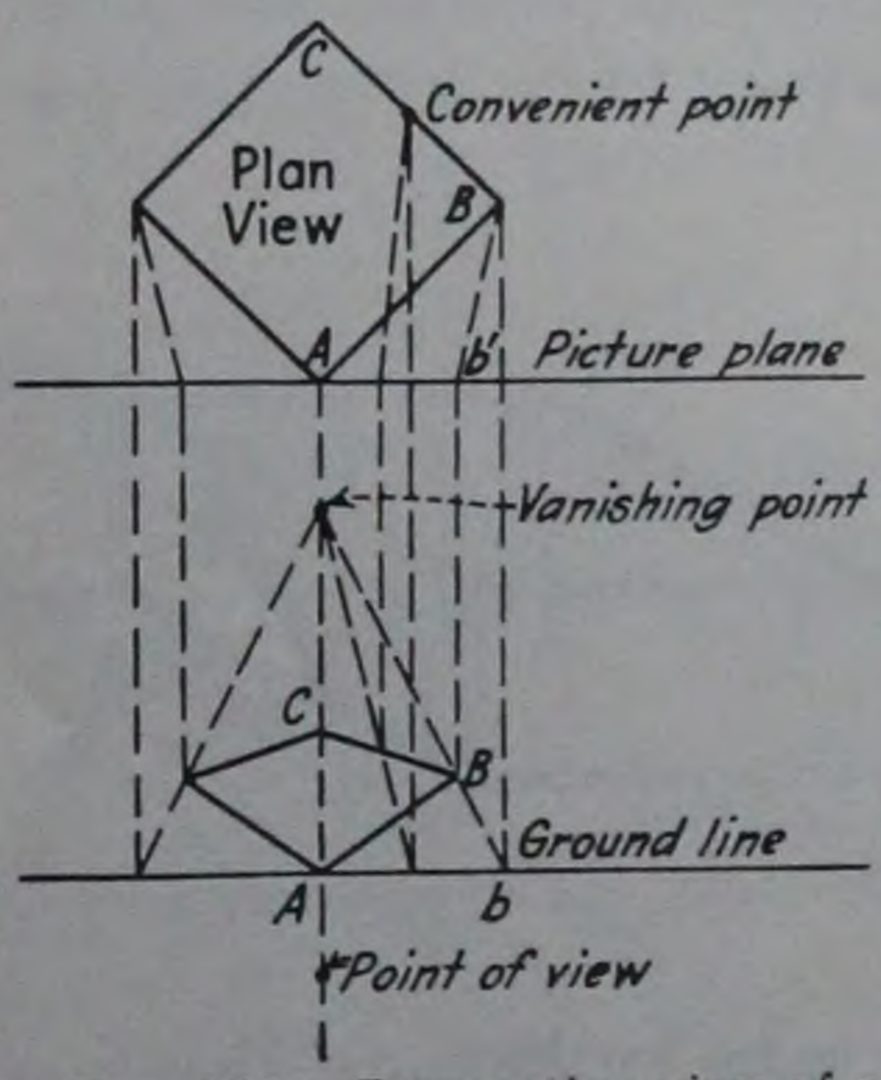


FIG. 196.—Perspective view of a rectangle with the point of view 5 ft. from the corner of the rectangle and 3 ft. above it.

c. The *ground line* is a horizontal line located so that the perspective will fall at the proper location on the final drawing.

d. The *vanishing point* is located on the principal axis as far above the ground line as the point of view is above ground (Fig. 196), 3 ft.

e. The picture plane is on a horizontal line drawn through the closest corner of the plan view. The picture plane may be moved from this location after some experience has been gained. The plan would appear on an imaginary plane located in a vertical position on the line representing the picture plane. If the drawing were made on a transparent sheet and placed in position on the picture plane, it would coincide exactly with the plan view as viewed from the correct point of view.

This completes the setup, ready for the actual drawing.

Procedure in Making the Perspective Drawing.—(*a*) Point *A* on the plan view will be located on the ground line at the point where the principal axis intersects it. (*b*) Point *B* is located as follows: Drop a perpendicular line from *B* on the plan view to the ground line intersecting it at *b*. Draw another line from this same point *B* to the picture plane *b'* so that if it were continued it would extend to the point of view. Drop a perpendicular line from *b'*. The point *B* on the perspective is located somewhere

on this line. To find the exact point, draw a line from *b* on the ground line to the vanishing point. The intersection of this line with the one dropped from the picture plane gives the exact location of *B* on the perspective. Point *C* in this setup is located on the principal axis, and therefore it will be necessary to select some convenient point on the line *BC* and secure its location on the perspective to determine the line *BC* on the perspective. Making a perspective consists of locating terminal points of lines and connecting them.

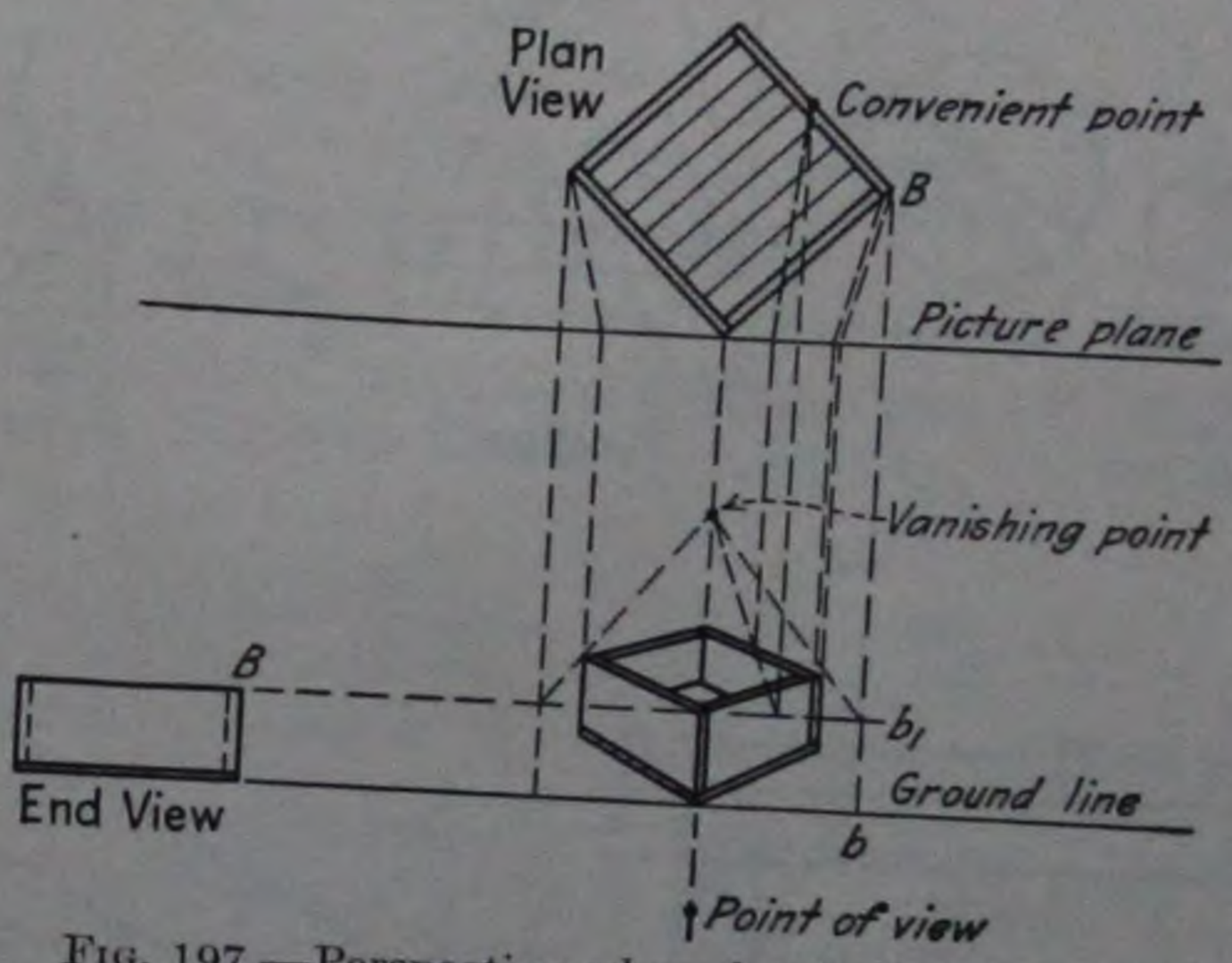


FIG. 197.—Perspective where height is involved.

Figure 197 shows a plan for making a perspective of a rectangular box. The procedure is similar to that used in drawing the rectangle, with the exception that there is one more dimension involved (height). A side or end view may be placed on the ground line and heights of different parts of the object projected to the proper lines for determining their height on the perspective. To determine the exact location of the top of the corner *B* on the perspective drawing, project the height from the end view to the line *Bb* at b_1 (Fig. 197). A line from b_1 to the vanishing point intersects a line dropped from the picture plane and locates the top of the corner *B* on the perspective.

Any perspective is drawn simply by locating points and drawing in connecting lines. After the principles have been mastered, much fill-in work may be done freehand.

233. Dimensioning Drawing.—*Dimension lines* must be made lighter than the lines in the drawing in order not to detract from the drawing itself. Certain conventions should be followed in order to make plans universally usable. Figure 198 shows a plan for dimensioning circles, angles, and arcs. In dimensioning short distances, the arrows are placed outside the limiting lines, and the figure representing the size is also placed outside. In dimensioning greater distances, the arrows may be placed outside

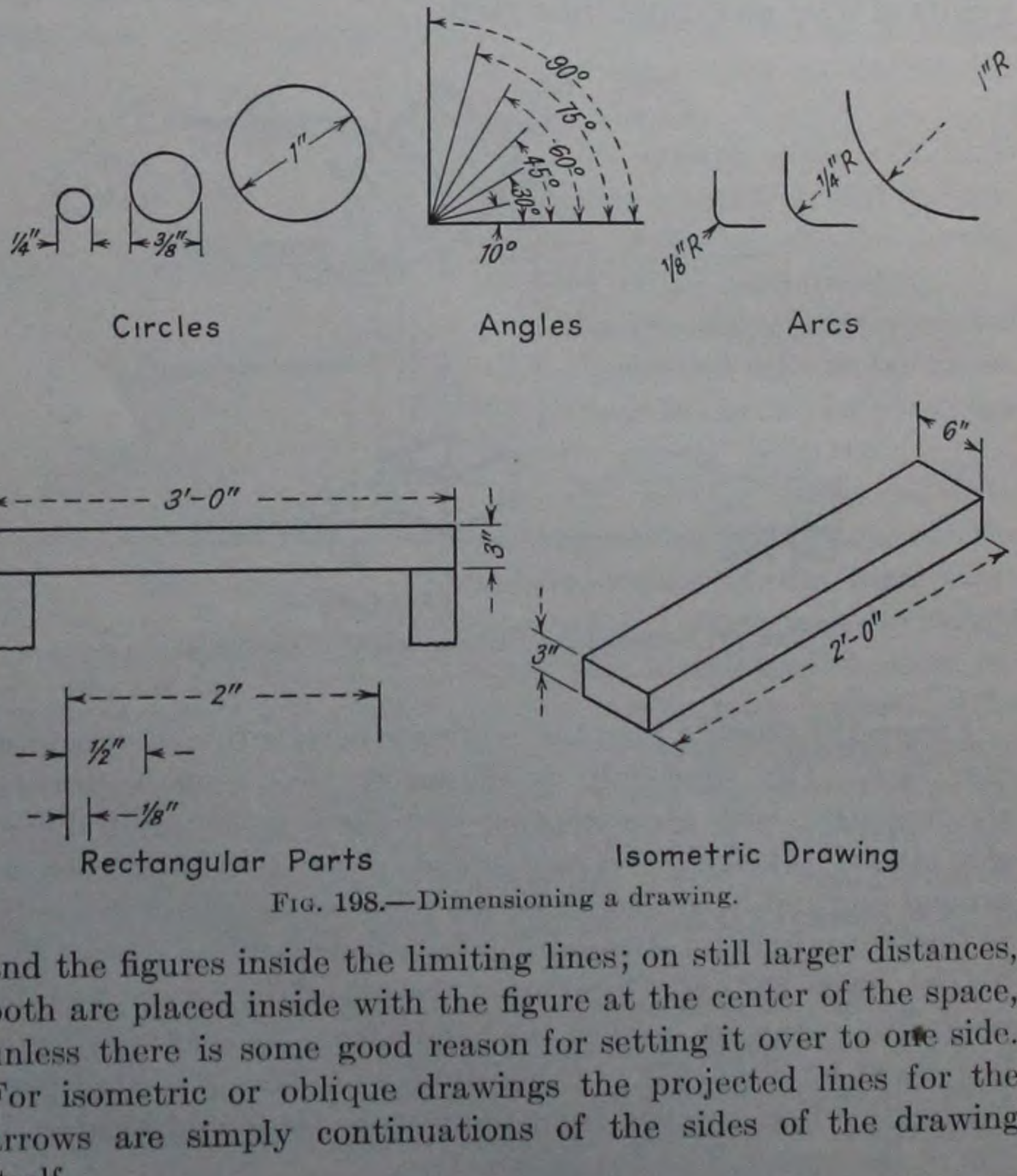


FIG. 198.—Dimensioning a drawing.

and the figures inside the limiting lines; on still larger distances, both are placed inside with the figure at the center of the space, unless there is some good reason for setting it over to one side. For isometric or oblique drawings the projected lines for the arrows are simply continuations of the sides of the drawing itself.

234. Symbols for agricultural drafting differ somewhat from those used in regular drafting because agricultural planning includes farm and farmstead layouts as well as building plans.

The symbols shown in Fig. 199 are suggested in order to standardize this work as much as possible. Detailed illustrations of building materials (grain of wood, individual brick, etc.) are not often used in working drawings. They can be used, however, if needed to clarify the design.

235. Drafting Equipment.—In considering the equipment necessary for drafting work, only the absolute essentials are

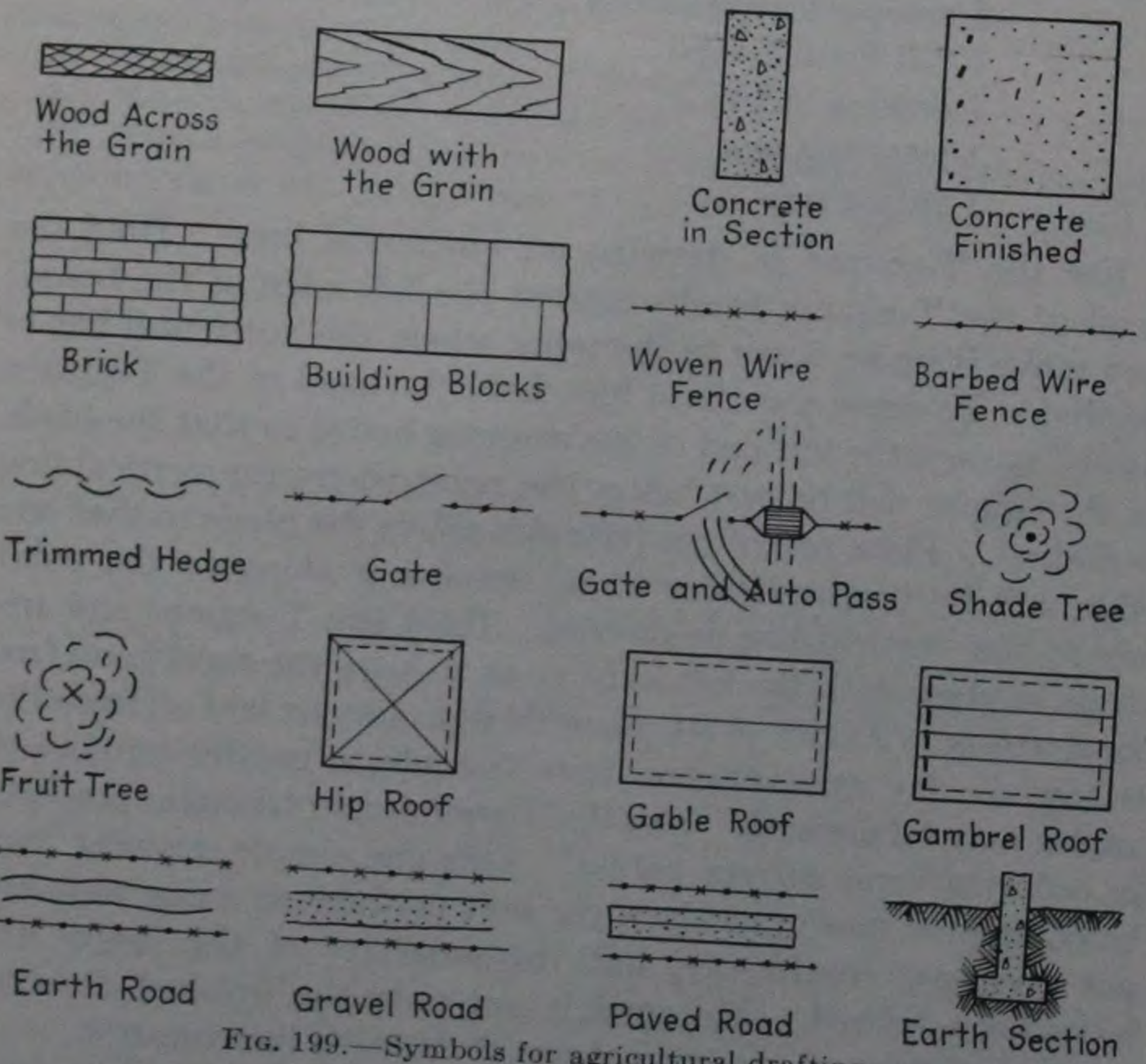


FIG. 199.—Symbols for agricultural drafting.

mentioned. For those who wish to do more advanced work later it would be good policy to purchase more complete equipment. See "Agricultural Drafting" by C. B. Howe, published by John Wiley & Sons, Inc., "Engineering Drawing," by French, McGraw-Hill Book Company, Inc., or any other good text on drawing for description of drawing tools. It is essential that a draftsman have the following equipment. Any reduction of this list means that he will not be able to do his work in a creditable manner.

1 combination drawing board 18 by 24 in.
1 T-square
1 30–60-deg. lettering triangle
1 45-deg. triangle
1 drawing pencil (4-H)
1 soft rubber eraser
1 boxwood architect's scale
1 compass attachment
1 roll Scotch tape
1 erasing shield
1 lettering pen
1 ruling pen

Use the T-square in drawing all horizontal lines. Hold the head of the T-square firmly against the left edge of the board, and move it up or down to the point where the horizontal line is desired. To draw a vertical line, hold the head of the T-square firmly against the left end of the drawing board so that the blade of the square will be just below the point where the vertical line is desired. Place one of the triangles above the blade so that one edge will be perpendicular to it, moving it along to the point where the vertical line is desired. Hold the T-square and triangle in place with the left hand so as to have the right hand free for drawing. Angles of 30, 45, or 90 deg. may be laid off from the triangles. By using two or more triangles a greater number of angles may be derived. Use the T-square and triangles properly in order to form correct habits. This one simple drawing may be completed more quickly if the best methods in using tools are not observed completely, but the objective of the lesson will have been missed. The goal is not only the finished drawing but a start toward the correct use of drawing instruments.

It is usually not practicable to make drawings of an object full size. Occasionally, however, it is desirable to draw small objects to actual size or even to larger than actual size in order to bring out details. In making these drawings, the boxwood architect's scale is very valuable. The most common scales used in drawing plans of small equipment are $\frac{1}{4}$ in. = 1 ft. or $\frac{1}{2}$ in. = 1 ft. For feeders and medium-sized structures a scale of 1 in. = 1 ft. or $1\frac{1}{2}$ in. = 1 ft. if often used. The scale used will depend on the size of drawing desired or the amount of detail that is needed. The boxwood architect's scale has 12 different scales on the six

edges available. Each of these is numbered from zero in feet divided into inches and fractions in case of the larger scales. Use the scale for laying off distances, but never use it as a straight-edge or ruler.

Questions and Problems

179. Make a projection drawing, top, side, and end view of a set of four steps; 8-in. rise, 12-in. treads; closed under steps and at the ends. (Scale, ½-in. equals 1 in. on all drawings.)

180. Make an isometric drawing of the same.

181. Make an oblique drawing of the same.

182. Make a perspective drawing of the same, picture plane to be through the nearest corner and point of view 10 ft. from the corner and 4 ft. high.

APPENDIX

SUGGESTED LABORATORY EXERCISES

I. Building-value Study.

Obtain census data on buildings for your state.

1. Make up a data sheet giving names of counties and the value of buildings per acre in each.

2. By adopting certain colors or crosshatching for certain values (as $7 to $8.99, $9 to $10.99, etc.) show the value of buildings for each county in the state on your map.

3. Determine the modal or most common value of buildings per county in your state.

II. Inspection Trip to Lumber Yard.

If arrangements are made in advance, most lumber dealers will be glad to detail one of their men to take the class through their yard and discuss the different varieties of wood stocked, the source of supply, the adaptability of different varieties to building work, grades of lumber and the way in which they are graded, manufactured shapes, problems of storage, sizes and lengths of wood stocked, kinds and grades of metal sheets stocked, and problems encountered in storage, kinds of clay and cement products stocked, problems in handling and storing cement, etc.

Write a report covering the foregoing points and any others that will add to the value of the report. Be a good listener, because the lumberman is volunteering his time for your benefit. If you take notes during the trip, make them brief. Write the report as much from memory as possible.

III. Testing Aggregate.

Run a test on an assigned sample of bank-run gravel. Use the field testing set recommended by the Portland Cement Association.

1. Determine the proportion of fine to coarse aggregate (*a*) by weight and (*b*) by volume. (Use ¼-in. screen.)

2. Determine the variation in size of particles in the aggregate. Plot a mechanical analysis curve, and compute the uniformity coefficient for the sample. Consult "Concrete Construction for Rural Communities," by Roy A. Seaton.

3. Determine the percentage of voids in the fine aggregate, the coarse aggregate, and then in a mixture of the two proportioned so that sand will fill voids in coarse aggregate. Use water to fill the voids, and from this compute percentages. (Add sand to water to secure complete penetration.)

4. Compute the yield per sack of cement (*a*) in a 1–4½ mix of cement and bank-run gravel as per original sample supplied. (*b*) In the mix planned to

secure maximum density. The specific gravity of cement is 3.1; of crushed rock, 2.49; and of sand and gravel, 2.65. The water-cement ratio is 6 gal. per sack in each case.

5. Determine the percentage of clay in the sample.

6. Write a report covering good and bad points found in each of the tests. Tell what might be done to improve the aggregate in each case. Report test data in tabular form. Include all calculations in indicated form. Be neat.

IV. Designing a Mix.

Design a mix for concrete aggregates, and compute the yield for a water-cement ratio of 5 and also for 7. If desired, a $\frac{1}{20}$ sack batch may be mixed. For the water-cement ratio of 5, mix the 0.25 gal. of water and the 4.7 lb. of cement, and then add as much of the fine and the coarse aggregates as you can and still have a workable mix. Maintain a proportion of about 1 to 2 between the fine and the coarse aggregates. (See the Portland Cement Association bulletin, Design and Control of Concrete Mixtures.) Weigh the supply of fine and coarse aggregates before using them, and then weigh the residue of each to determine the amounts used. When the mixing has been completed, pour the concrete into forms of suitable size and shape for later inspection or testing. Float and trowel the surface. Repeat this procedure with the 8 water-cement ratio. Inspect the samples at the end of a 27-day period for appearance of the finished surface, density of the concrete, and, if possible, determine the strength of the concrete in each case. Make a written report of your work, including methods of judging workability during the mixing and the observations and tests made on the 27-day-old specimens.

V. Strength of Wood in Bending.

Determine the maximum strength of different varieties of wood in bending. If a regular testing machine is available, the tests will be easily arranged.

No. of test	Variety of wood	Size of beam*			SM	Safe fiber stress (Sfs)	Computed safe load (W)†	Allowable deflection	Load at allowable deflection	Load to break (W_1)	Maximum fiber stress at failure‡
		d	b	L							

* All dimensions in inches.

† $W = \dfrac{(Sfs)bd^2}{1.5L}$.

‡ Maximum fiber stress $= \dfrac{1.5W_1L}{bd^2}$.

FIG. 200.—Suggested data sheet for testing strength of wood.

If no such machine is available, a post-testing machine may be used. Specimens ¾ by 2 by 30 in. can be handled in such a machine. Make up a data sheet (see Fig. 200), and record results of tests conducted. Write a report giving information on deflection and strength of beams made from different varieties of wood, differences in the appearance of broken specimens, possible differences in compressive and tensile strength of different varieties of wood as evidenced by the broken specimens, evidence of vertical or horizontal shear, etc. Include test-data sheets and computations as a part of the report.

VI. Holding Power of Nailed Joints.

Make up a number of nailed joints in such shape that they can be stressed to failure in a testing machine. Different sizes and kinds of nails and methods of clinching can be tried. Specially treated nails may also be tested. In Fig. 201 is shown a recommended sheet for recording data on the holding power of nailed joints.

Write a report of the tests, covering the reliability of the rule for calculating the holding power of nails, the effect of clinching nails in different ways, the influence of the size and kind of nails on their holding power, the holding power of different varieties of wood, and the most common type of failure in clinched joints (clinches straightening and pulling through, heads pulling through, splitting of stock—first piece and second piece, etc.). If time permits, conduct tests to determine the number of nails fastening a 1 by 4 in. to a 2 by 4 in. at which the law of diminishing returns begins to apply. Include a data sheet with your report.

Trial No.	First piece		Second piece		Size of nail	Number of nails	Kind of nails	1 2 3*	Computed load to break	Per nail	Load to break in test	Per nail	Per cent error for
	Size	Variety of wood	Size	Variety of wood									

* 1 = clinched; 2 = not clinched; 3 = not driven through.

FIG. 201.—Recommended data sheet for recording data secured in testing holding power of nailed joints.

VII. Inspection Trip to Observe Construction Details of Barns (preferably two barns with different types of construction).

1. Observe the following points on construction: type of framing, type of roof design, roof framing and bracing, support of floor joists at walls, support of floor joists in center of building, wall or roof supports over doors and other openings, and type of siding and roofing used. (Use sketches to illustrate.)

2. (*a*) Select the joists having the longest span, and figure the factor of safety used. (*b*) Select one column carrying the heaviest load, and figure the factor of safety for it. (*c*) Compute the factor of safety used in the girder at the point where it will be subjected to the greatest load.

3. Make a list of points of failure in the structure and give causes, if they can be determined. Inspect the building for points of excessive depreciation, and, if possible, determine the cause for each of these failures.

4. Make a report on each barn inspected, giving the information outlined in this excercise. Add any additional data needed to make a more complete report.

VIII. Gable-, Combination-, and Gambrel-rafter Layout.

Secure stock, and lay out a pattern for rafters as assigned by your instructor. Figure 202 shows a suggested work sheet for this exercise. Write your name on each piece before leaving the laboratory.

Write a report explaining the setting of the square, giving methods and computations for securing length of rafters and defining the different terms used in describing roof pitches and cuts.

Kind of roof	Width of building*	Pitch*	Horizontal projection desired*
Gable			
Combination			
Gambrel			

* To be filled in by instructor according to stock available.

FIG. 202.—Suggested work sheet for rafter layout.

IX. Hip- and Jack-rafter Layout.

1. Lay out one hip rafter and one jack rafter for a building _____ ft. wide, _____ ft. long, with a roof pitch of _____. Write your name on each piece before leaving the laboratory.

2. Write a report describing the methods used in laying out the different cuts, computing length, etc.

3. Make a sketch showing a top view of the rafters and plates for the building.

X. Heat Loss from a Building.

In Fig. 203 is shown a suggested record sheet for tabulating data secured in computing the heat loss from an assigned building (preferably a barn with a ventilation system). Determine the weighted value of U for the structure.

Name of building _____

Description of wall	Area, less doors and windows	Value of U	Btu loss per degree difference in temperature
Description of windows	Area, square feet		
Description of doors	Area, square feet		
Description of ceiling	Area, square feet		
Infiltration around windows	Length of crack	Infiltration, cubic foot	
Infiltration around doors			

Weighted value of U for the structure = _____

FIG. 203.—Suggested record sheet for tabulating data secured in computing the heat loss from a building.

XI. Test of a Ventilation System (use the same building as for exercise X).

This exercise can be carried out to best advantage on a cold night after chores have been completed. Conditions at this time will be more stable

than at other times, when doors are being opened and feeding operations are being carried on. The equipment needed consists of three or more thermometers, one hygrometer, and one or more anemometers.

Make up a data sheet similar to the one shown in Fig. 204.

Write a report of the test giving the amount of air change through the ventilation system; through infiltration (see exercise X); amount of heat produced in the barn (calculated); theoretical temperature difference (calculated); actual temperature difference found in tests. Account for the difference between calculated and actual temperatures, if any.

Report on condensation, if any; frost, if any. At what inside relative humidity would condensation begin to form on walls? Give percentage efficiency of the system as a whole.

Show a sketch of the ventilation system as a part of your report.

Time of day (hours-minutes)	Outside		Inside		Outtake flues				Inlet openings
					A	*A*	*A*	*A*	Total area
	Temperature	Relative humidity	Temperature	Relative humidity	Velocities				Average velocity
					1	2	3	4	

FIG. 204.—Suggested data sheet for recording test on ventilation system.

XII. Field Trip to Dairy Farms (preferably one with a loafing barn and milking room and the other with an individual stall-type barn).

1. Make sketches of the floor plan for each layout.
2. Note the degree of compliance to milk-ordinance requirements in each.
3. Observe features that make for convenience in handling cows and in caring for milk.
4. Observe equipment used in the milkhouse.
5. Write up in chronological order each step in the procedure that the farmer follows from the time the cows are brought into the barn until the milk is bottled, ready for delivery.
6. Compare the two sets of equipment, including points outlined for observation and any others that you may find valuable in more completely describing them. Include sketches with your report.

XIII. Inspection of Silos (visit at least three different types of silos).

1. Describe the silo, giving location, general type, size, and, if possible, the date of construction.
2. What material is being used for silage? Is there evidence of leakage? Spoilage?
3. Is there evidence of damage to the silo from action of acids? From pressure? From loads on foundation? From downward pressure on walls?
4. What provision is made for entrance of filler pipe? For removal of silage? For drainage from silo?
5. What would you consider the weak points in the silo?
6. What is the first and the annual cost of each of the silos? Annual cost per ton of storage for each type?
7. Write up a report on each silo visited, including observations and computations.

XIV. Appraisal of a Set of Farm Buildings (the class may be divided into groups and each group assigned to a building with an exchange of data following in order to facilitate the work).

In Fig. 205 is shown a suggested sheet for recording data in an appraisal of a set of farm buildings.

XV. Arrangement of Buildings on the Farmstead.

Select a set of buildings suited to a 160-acre farm on class No. 2 land having 96 acres in cultivation, 50 acres in permanent pasture, 9 acres in timber, and 5 acres in the farmstead. Select enterprises to suit a locality with which you are familiar.

Draw two floor plans for each building to a scale of $\frac{1}{32}$ in. = 1 ft. Cut these out so that they can be moved to secure a desirable grouping. Plan arrangements of these buildings, using the central court system, one set for a _____ front and one for a _____ front. Paste these in place when you have them located satisfactorily. Show fences, gates, drives, windbreak, shade and ornamental trees.

XVI. Inspection Trip to Clay or Cement-products Plant.

If arrangements are made in advance, most manufacturers will be glad to detail a man to take the class through the plant.

Points of interest will be source and quality of materials; completeness of supply; methods of mining, transportation, processing or manufacturing, curing, and storing; the different types of manufactured products; uses made of the products; etc.

Write a report of the trip covering the above points and additional information that will increase the value of the report.

General information: Name of owner _____
Address _____
Acres in farm _____ Classification of land _____
Acres in cultivation _____
Acres in pasture _____
Livestock for best land use:

Dairy cows _____	Beef cows _____	Horses _____
Yearlings _____	Yearlings _____	Colts, one year _____
Calves _____	Calves _____	Colts, two years _____
Ewes _____	Sows _____	Hens _____
Lambs _____	Hogs _____	

Name of building								
Age to date								
Estimated future service								
Units cost								
Cubic contents								
Replacement cost								
Depreciation								
Structural present worth								
	Available	Needed	Available	Needed	Available	Needed	Avail	
Horse stalls								
Cow stalls								
Farrowing pens								
Pen space, square feet								
Hay storage, cubic feet								
Grain storage, cubic feet								
Corn storage, cubic feet								
Size silo								
Space for hens								
Percentage usefulness								
Appraised value								

FIG. 205.—Suggested record sheet for recording data secured in appraisal of a set of farm buildings.

LIST OF VISUAL AIDS

The following list of 16-mm motion pictures and 35-mm filmstrips can be used to supplement some of the material in this book. These films may be obtained from the producer or distributor listed with each title. (The addresses of these producers or distributors are given at the end of the bibliography.) In many cases these films can also be obtained from your local film library or local film distributor.

The running time (min) and whether it is silent (si), sound (sd), or filmstrip (FS) are listed with each title. All those not listed as in color (C) are black and white.

Trees for Tomorrow (Castle 18 min sd). Shows conservation practices and how plywood aircraft, prefabricated houses, raw materials for vital chemicals, cellophane, plastics, and clothing are being made from trees.

Trees and Men (Weyerhaeuser 44 min sd). Shows the story of logging and reforestation and a historic sequence of the development of the lumber industry in the Pacific Northwest.

Trees and Homes (Weyerhaeuser 30 min sd C). Shows conservation practices: logging and manufacturing of lumber, plywood, etc.

Harvesting the Western Pines (Western 30 min sd). Shows selective logging operations and modern lumber industry methods.

Fabricating the Western Pines (Western 35 min sd). Shows logging methods, sawmill operations, fabrication of sashes, doors, frames, etc., and installation.

Doorway to Happiness (Douglas 30 min sd C). Gives a brief logging scene, then a complete description of the manufacture of doors, the millwork involved, and shows finally how doors should be used and cared for in the home.

Plywood, the Miracle Wood (Douglas 35 min sd C). Shows manufacture and uses of plywood.

Plywood on the Farm (Douglas 30 min sd C). A survey of important uses for plywood on farms, such as portable service buildings, dairy and horse barns, chicken brooders, house remod-

eling, etc., and a brief description of its physical properties are given.

Prefabrication with Plywood (Douglas 35 min sd C). Surveys the entire prefabrication industry and gives details for factory prefabrications, house erection, and a discussion of the future possibilities of building houses, farm buildings, and commercial structures by this mass-production method.

How to Finish Plywood (Douglas 22 min sd C). Shows how plywood is finished, *i.e.*, painted, stained, enameled, wallpapered, to create the proper interior and exterior finishes.

Building a Home of Western Pine (Western 25 min sd). The step-by-step construction of a house is shown.

The Will and the Way (USDA 30 min si). Shows the remodeling and modernizing of an old farmhouse.

Repainting a Frame Building (USOE 18 min sd). Shows how to determine repairs needed on building before painting; how to estimate amount of paint to be used; how to prepare building for paint job; how to set up staging; how to prepare factory- or home-prepared paint; how to prime coat the building; how to store paint and equipment; and how to care for brushes.

Block That Termite (USDA 20 min sd). Shows the methods of protecting buildings against termites.

Story of Rock Wool Home Insulation (Bur. Mines 25 min sd). The use of insulation in the home.

Adobe Bricks (Bailey 8 min si). Materials used, methods of mixing, forming, drying, and use of adobe bricks.

Making the Adobe Brick (A&B 15 min si). The entire process of making adobe brick and using it in construction is shown.

From Mountain to Cement Sack (Bur. Mines 15 min si). Manufacture of Portland cement and preparation for market.

Granite—A Saga of Stone (Harmon 15 min si). Shows the story of granite: how it is mined, finished, and some of its important uses.

Farm Inconveniences (Int'l Harvester 10 min sd). Shows the results of carelessness on the farms as contrasted with orderly practices.

Worst of Farm Disasters (USDA 10 min sd). Shows how proper installation of electricity can help prevent farm fires.

Electricity on the Farm (TVA 30 min si). Its use in rural areas is shown.

Bringing an Old Wisconsin Farm House up to Date (USDA FS). At small cost, a dairy-farm family made over, from foundation to roof, an old timber house with lumber from their own woods and now live in a comfortable modern dwelling.

Use of Logs in Farm Buildings (USDA FS). Shows how logs can be utilized for most farm buildings.

SOURCES OF THE FILMS LISTED ABOVE

A&B—Akin & Bagshaw, Inc., 1425 Williams St., Denver, Colo.
Bailey Film Service, 1651 Cosmo St., Hollywood, Calif.
Bur. Mines—Bureau of Mines, Experimental Station, 4800 Forbes St., Pittsburgh 13, Pa.
Castle Films, 30 Rockefeller Center, New York 20.
Douglas Fir Plywood Association, 301 Tacoma Building, Tacoma, Wash.
Harmon Foundation, 140 Nassau St., New York 7.
International Harvester Co., Inc., 180 N. Michigan Ave., Chicago.
TVA—Tennessee Valley Authority, Knoxville, Tenn.
USDA—U.S. Department of Agriculture, Motion Picture Extension Service, Washington, D.C.
USOE—U.S. Office of Education. (Can be obtained from Castle Films.)
Western Pine Association, Yeon Building, Portland, Ore.
Weyerhaeuser Sales Co., First National Bank Building, St. Paul, Minn.

INDEX

A

Absolute humidity, 141
Absolute volume, 178
Accessibility, to fields, 38
  to highway, 36
Aggregates, kind of, 173
  quality of, 174
  tests for, 174
Air movement for comfort, 132
Animals, space for, 16
Annual cost of buildings, 34
Annual depreciation, 25
Appearance of farmstead, 48
Apple storage, 286
Appraisal of buildings, 25
Architecture, 298
Arrangement of buildings, 36
Attractiveness of dwellings, 302
Auto pass, 60

B

Bacteria, septic-tank, 324
  wood-decay, 161
Balloon frame, 216
Barns, beef-cow, 108
  frames for, 216
    balloon, 216
    pole, 215
    post, 215
  raising, 5
  work-stock, 116
Bathroom, location of, 298
Beams, types of, 288
Bearing power of soils, 219
Bedrooms, number needed, 294
Beef cows, barn requirements of, 107
  barns for, 108
Bending moment, 226
Bent rafter and frames, 216
Bins, grain, 271
  portable, 274
  potato, size for, 290
Bird's mouth, 240
Blocks, building, 194
  clay, 196
  corner, 195
  L-, 196
Bolts, 170
  spacing of, in joints, 171
Box plate, 220
Bracing, 222
  of corner posts, 55
  of end structure, 223
  of house walls, 311
  plate, 223
  of roofs, 223
Breeding costs, 23, 24
Breeding requirements, 2, 6, 7
Breeding zones, 133
Brick, 190
  kinds of, 191
  manufacture of, 191
  testing of, 192
Brick wall, ideal, 193
  Rolok-bak, 194
Bridging, 311
British Thermal Unit, 123
Brooder house, 93
  arrangement of, 41
  outdoor type of, 94
Buildings, appraisal of, 25–28
  use value of, 27

C

Cantilever beams, 228
Carpenter, country, 5
Carrying capacity of land, 14
Casement windows, 297
Cement, Portland, 173

Center supports in basement, 308
Central grain storage, 268
Central hog house, 102
Chimney, 314
Chopped hay, 265–267
Chore equipment, 105
Chore routes, 74
Circulating heater, 154
Classification of buildings, 22
Clay products, 190
Clay-block silos, 280
Clinching nails, 169
Cobblestone, 186
  forms for, 187
  foundation for, 186
Columns, long, 235
  short, 234
  steel, 235
Combination rafters, 242
Comfort, air movement for, 132
  definition of, 130, 300
  humidity for, 130
  temperature for, 130
Comfort zones, 133, 301
Common lumber, 164
Concrete, curing of, 181
  definition of, 173
  estimating quantities of, 176
  mixing of, 180–181
  reinforcing, 182, 236
  surfacing, 181
  trial batch of, 175
Concrete blocks, 184, 196
  silos of, 281
Concrete joists, 185
Concrete products, 184
Concrete stave silos, 280
Condensation, computation for, 143
  damage from, 141
  in walls, 144
  on windows, 142
Conduction, 124
Confinement system for hogs, 98
Connectors for woods joints, 171
Continuous beams, 229
Contour farming, 38
  fencing in, 58
  field arrangement in, 58
Convection, 124
Court, central, 41
Crib, for cow, 270
  pressures on walls of, 273
Crib floors, 272
Crushing across grain, 232
Cubing, 25
Curing, of cobblestones, 189
  of concrete, 181

D

Dairy barn, conventional style, 78
  environment of, 71
  lighting of, 66
  loafing, 81
  one-story, 81
  planning of, 62
  stalls for, 75
  T-shaped, 79
  ventilation in, 68
  width of, 77
Dairy cows, 63
  heat produced by, 140
  moisture produced by, 141
Defects in lumber, 165
Depreciation, 25
Design, 209
Dimensioning drawings, 332
Dipping vats, 114
Distribution, of loads, 226
  of stored grain, 269
Division of labor, 4
Dormers, 315
Drafting equipment, 334
Drafting symbols, 333
Drafts, 87
Drainage, farmstead, 38
  roof, 206
  spouting in, 206
Drawing, dimensioning, 332
  isometric, 328
  oblique, 329
  perspective, 329
  picture plane in, 330
  projection, 328
Drinking cups, 72

Dust, 62
Dwelling, location of, 44

E

Efficiency, building, 9
  farmstead, 47
  house, 293
Egg storage, 94
Electric heating, 158
Enterprises, to fit farm, 11
  isolation of, 46
Estimating, breeding cost, 18, 19, 21
  cold-storage materials, 180
  concrete materials, 176–178
Excavation, 307
Expanding markets, 4

F

Factor of safety, 229
Failure of breedings, 206
Farming, self-sufficing, 2
Farmstead, accessibility of, 36
  arrangement of, 36
  central court, 41
  drainage of, 38
  efficiency of, 47
  location of, 36
  outlook of, 41
  replanning of, 50
  windbreak for, 40
Fascia cut, 240
Feeder cattle, housing for, 110
Feed-grinding room, 78, 289
Frame, roof of, 54
  kinds of, 53
Fence posts, 55
Finish lumber, 264, 315
Fire protection, 48
Fireplace, 158, 214
Fitting buildings to the farm, 11
Floors, reinforced concrete, 336
  subfloors, 313
Flues, 62
Footings, house, 210, 306
Forms, cold-storage wall, 187
Foundations, barn, 218
  silo, 278
  stresses in, 218
Frames, balloon, 216
  center support of, 308
  pole, 215
  post, 215
  semicircular, 216
  steel, 217
Fresh-air inlets, 151
Fuller's rule, 177
Furnace, grate area of, 157
  hot-air, 156

G

Gable rafters, 241
Gambrel rafters, 245
  length of, 246
Gates, 59
General purpose barn, 119
Glass area per cow, 67
Gothic rafters, 248
Grain storage, 268
Grain-silage pressure, 270
Grate area, of circulating heater, 155
  of warm-air furnace, 156
Gravel washing, 175

H

Hay, baled, 265
  chopped, 265–267
Hay keeper, 206
Headers over doors and windows, 311
Heat, production of, by animals, 120
  transfer of, 124
Heat losses, 126, 134, 135
  measurement of, 123
  from pipes, 156
Heating systems, circulating heater, 154
  electric, 158
  fireplace, 158
  steam, 157
  warm-air, 156

Hip rafters, 252, 254
Hip roof, definition of, 252
plan of, 253
Hog enterprise, 97
Hog houses, 98, 102
Hog waterer, 101
Horse barns, 116–117
Horse stalls, 118
House, architecture of, 302
cost of, 18
design of, 307
efficiency of, 203, 293
equipment for, 299
location of, 44
outlook from, 44, 302
planning of, 292, 304
Humidity, absolute, 141
apple-storage, 287
comfortable, 130
potato-storage, 289
relative, 141

I

Individual hog house, 109
Individual stall barn, 74
Inlets, fresh-air, 151
Insulation, kinds of, 126
special methods of, 126
Insulation materials, 203
Investments, for dairy enterprise, 30, 33, 34, 63
for poultry enterprise, 32, 34
returns from, 29
Iowa roof truss, 247
Isometric drawing, 328

J

Jack rafters, 255
Jamb blocks, 196
Joints, bolted, 170, 171
nailed, 167, 169
Joist hangers, 222
Joists, concrete, 185

K

King ventilation standards, 146–147
Kitchen equipment, 203

L

Labor, division of, 4
farm, 6
plans for, 293
saving, 63
Land use, 11
Laying house, 87
Lettering, 326, 327
Livestock compound, 120
Loads, application of, 226
snow, 225
wind, 225
Loafing barn, 81, 83, 85
Log houses, 3
Lumber, defects in, 165
grades of, 164

M

Machinery, repair shop for, 236
storage factor of, 257, 261
use of, 258
Mangers, dairy, 76
Manure, disposal of, 65
storage of, 65
value of, 66
Markets, 12
Masonry barns, 218
Material, strength of, 230
Metal sheets, 199
for roofing, 203
for siding, 199
Milkhouses, 72, 169
ordinance governing, 65
Milking parlor, 82
Moisture, capacity of air for, 141
production of, by animals, 140
Mortar, 188, 193

N

Nails, clinching, 169
kinds of, 167
quantities of, needed, 168
sizes of, 167
Nests, 88

O

Oblique drawings, 329
Open sheds, 112, 261

P

Paint, value of, 207
Paper, building, 202
Partitions, 329
Perspective drawing, 329
Pitch of roofs, 239
Plancher cut, 240
Planning houses, 304
Plate, box, 220
Plumbing, 319
Pointing cobblestone, 188
Pole frames, 215
Portland cement, 173
Post frames, 215
Poultry housing, costs of, 92
  equipment for, 88
  remodelling of, 214
Privies, 320
Projection drawing, 328

Q

Quality products, 8

R

Radiation, heat, 124
Radiator size, 157
Rafters, bent, 249
  combinations of, 242
  gable, 241
  gambrel, 245
  Gothic, sawed, 248–249
  hip, 252
  jack, 255
  length of, 242
    square-root method of determining, 241
  shed, 243
Range shelter, 94
Rat fenders, 273
Real estate value, 11
Recreation room, 298
Reinforcing, cobblestone, 188
  concrete, 182
  floor, 236
  kinds of, 184
Relative humidity, 89, 141
Remodelling, 209
Repair, state of, 209
Repairing, foundation, 211
  roof, 211
Reroofing, 203
Ribband board, 222
Roll roofing, 201
Rolok-bak wall, 194
Roof, semicircular, 250
Roof design, 315
Roof projections, 317
Roof trusses, Gothic, 248
  Iowa, 247
  semicircular, 217
  Shawver, 247
  wing-joist, 246
Roofing, kinds of, 200
  life of, 208
  repair of, 211
Rutherford ventilation, 147

S

Safety factor, 229
Sanitation, 46
Screens, 65
Seal of quality, 200
Septic tank, 323, 325
Service buildings, 46
  central service court of, 41
Sewage disposal, 323
Shawver truss, 247
Shear, 231
Sheathing, diagonal, 311
Shed rafters, 243
Sheep barns, 113
Shingles, 200
Shop and garage, 263
Siding, 198
Silage, cost of, 275
  weight of, 277

Sills, 309
Silo, concrete block, 281
foundations of, 278
kinds of, 279
location of, 277
pressure in, 279
size of, needed, 276
Silt test, 174
Simple beam, 228
Siphon, automatic, 325
Size of septic tanks, 324
Snow loads, 225
Snow-fence silo, 282
Sod houses, 3
Soil, bearing power of, 219
Spouting, 206
Square, carpenter's, 238
Stairs, 312
Stall, 75
Standards for buildings, 20
Steel barn frames, 217
Steel beams, 232
modulus of section of, 233
Steel columns, 235
Stepping off with square, 242
Storage, apple, 286
central, 269
distributed, 269
grain, 268
hay, 265
machinery, 257
potato, 288
Strength of material, 230
Stresses, 226
Summer range shelter, 94
Sunshine efficiency, 100

T

Temperature, for apple storage, 287
comfortable, 89, 130, 301
computation for, 136
control of, 91
Termites, 163
Testing, of aggregates, 174
of brick, 192
Trench silos, 283
Trusses, Gothic, 348
house-partition, 310, 329
Iowa, 247
semicircular, 217
Shawver, 247
wall, 312
wing-joist, 246

V

Ventilation, with flues, 150
gravity type, 147
King system of, 146
mechanical, 152
need for, 146
New York system of, 147
open-front, 90
Rutherford system of, 147
Volume, absolute, 178

W

Wall, ideal brick, 193
Rolok-bak, 194
Wall covering, 314
Water systems, 321
Water-cement ratio law, 175
Waterproofing, 307
Weight of materials, 227, 277
White potatoes, storage of, 289
Wind loads, 225
Windbreak, 49
Windows, 315
height of, 99
Wing-joist truss, 246
Wood, 161
Wood-hoop silo, 281
Wood-stave silo, 279
Work animals, 116
Work surfaces, 299
Workrooms, 294

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